

Alternatives for Municipal Wastewater Management Systems

for small, rural communities
in
New York State



*DeLancey Septic Maintenance District
Town of Hamden, Delaware County
New York State*

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Introduction

In New York State, residents are struggling to find solutions to wastewater problems in their communities. Funding for construction of new or upgraded systems is scarce. Septic systems are failing, and communities often lack local wastewater management programs to address the problems. Communities must also address a myriad of local, regional and state requirements, and even more requirements in specially-regulated watersheds.

There are many solutions available that address wastewater issues, from implementation of a wastewater management program for individual on-site septic systems to construction of centralized sewers and a wastewater treatment plant. The process of developing an appropriate solution can be confusing and frustrating for municipal leaders.

This manual was conceived by the Delaware County Planning Department and funded by the Appalachian Regional Commission. It is intended to be used as a tool for communities, whether inside or outside a regulated watershed, to help them understand the types of technologies and management programs that may work for their particular situation. This manual describes wastewater treatment system technologies and discusses treatment systems that are appropriate for small, rural communities in New York State. This manual is not intended to replace regulatory agency staff expertise or the services of licensed engineering professionals, which are essential to any public works project.

There are many other valuable sources of information for wastewater technology and management programs, especially the United States Environmental Protection Agency, the New York State Department of Environmental Conservation, the New York State Department of Health, the National Small Flows Clearinghouse, the National Environmental Services Center at West Virginia University, and the Massachusetts Alternative Septic System Test Center in Sandwich, MA.

A literature search was completed before beginning this manual. The process undertaken to complete the literature search and the reference list is included in Appendix A.

A companion guidance document produced by the program sponsors and authors, *The Guide to Developing a Municipal Wastewater Project for Small, Rural Communities in New York State*, is also available. That document focuses on the procedures of developing a community wastewater management system; this manual focuses on technical alternatives for a community wastewater management system.

Word Play

Wastewater industry terms may have different or additional meanings than the same terms used in every day language. For instance, the common usage of the term “decentralized” would indicate a wastewater system that serves a single parcel or something less than the entire community, i.e. the opposite of a “centralized” system which in common usage would indicate a single wastewater system serving an entire community. However, if a system utilized subsurface wastewater treatment and disposal, in the wastewater industry that system is still considered “decentralized” even if it serves an entire community and incorporates community-wide sewers. In the wastewater industry, a “centralized” wastewater system refers only to a system of community-wide sewers and a wastewater treatment plant.

The following definitions are from: The *USEPA Handbook for Managing Onsite and Clustered (Decentralized) Wastewater Treatment Systems*, 2005, EPA No. 832-B-05-001:

1. Centralized Wastewater System. A managed system consisting of collection sewers and a single treatment plant used to collect and treat wastewater from an entire service area. Traditionally, such a system has been called a Publicly Owned Treatment Works (POTW) as defined in 40 CFR 122.2.
2. Decentralized Wastewater System. An onsite or clustered system used to collect, treat, and disperse or reclaim wastewater from a small community or service area.

The following definitions are from: The *USEPA Onsite Wastewater Treatment Systems Manual*, 2002, EPA/625/R-00-008:

1. Centralized wastewater treatment system. A wastewater collection and treatment system that consists of collection sewers and a centralized treatment facility. Centralized systems are used to collect and treat wastewater from entire communities.
2. Decentralized system. Onsite and/or cluster wastewater systems used to treat and disperse or discharge small volumes of wastewater, generally from dwellings and businesses that are located relatively close together. Decentralized systems in a particular management area or jurisdiction are managed by a common management entity.

Word Play (Cont'd.)

Unfortunately, even these two publications do not quite agree on the definitions of centralized and decentralized wastewater systems.

Note that the USEPA Handbook of 2005 uses definitions much the same as those presented as the industry standard in paragraph one (1) above, while the USEPA Manual of 2002 uses somewhat different definitions which in turn use words in a way somewhat closer to common English usage.

Further, the practitioners in the wastewater industry are not always using the terms in accordance with any of USEPA's definitions. Though EPA's 2002 definition does not limit centralized to wastewater treatment plants and decentralized to subsurface treatment and disposal, a large group of practitioners does so, and EPA's 2005 definitions follows the industry standard, so we have adopted that set of definitions.

Similarly, the words "onsite", or "on-site", are used by the industry to describe a system that may be on the individual property which the wastewater system serves, as the common definition of the word would indicate, but these words often also refer to any system that has subsurface treatment and disposal.

Throughout this manual, whenever possible, standard wastewater industry terms are used so that the manual is consistent with other wastewater publications and reference material. In cases where these terms may be confusing or clearly opposite of the common understanding of the word, explanations and definitions are provided.

Treatment System Types and Issues

Most communities will eventually need to solve some sort of wastewater problem. Understanding the types of systems that will solve these problems brings the decision maker another step closer to providing a safe environment for the community.

There are many types of wastewater technologies that can be combined into a wastewater collection, conveyance, and treatment system. Most of these systems can be placed in two main categories: the centralized system and the decentralized system.



*Village of Whitney Point
Wastewater Treatment Plant
Broome County, New York State*

Centralized System.

A centralized system refers to the type of wastewater treatment and disposal typically used in municipal population centers such as villages and cities. Centralized systems are typically comprised of large diameter (eight inch or larger) gravity collection system pipes to carry raw sewage directly from the homes and business to a central facility where the sewage is treated and discharged directly to a stream (surface discharge). Centralized systems are required for significant wastewater flows or highly polluted wastewater. Centralized systems treat the sewage through biological, mechanical and chemical processes in order to prepare the wastewater to be legally discharged to a body of water without posing a health threat to the public or creating an environmental problem.

Centralized System

A managed system consisting of collection sewers and a single treatment plant used to collect and treat wastewater from an entire service area.

Centralized System Issues. Centralized systems have a number of advantages that have made them the traditional choice of communities where building density and site features allow. Since centralized systems are monitored to ensure that they meet regulatory discharge limits, centralized systems must be well-managed to meet performance requirements. Also, centralized systems generally are associated with a management structure with a more reliable revenue stream. They have also long been the focus of federal and state funding assistance programs.

Centralized wastewater systems are not without problems. Many systems are plagued with old and failing collection system mains and appurtenances. Plant components wear out and costly upgrades may be required to keep pace with changing water quality requirements and growing populations. Operation and maintenance (O&M) costs are generally higher per gallon treated than those costs for decentralized systems. Centralized O&M costs continually rise with inflation. As funding sources decrease, financing new or upgraded centralized systems is more difficult. System users become reluctant to approve new infrastructure projects or upgrades to existing systems that will further increase annual user fees.

Ancient History

Early waste removal oftentimes involved direct discharge to surface waters that contaminated lakes, ponds, streams and coastal waters and in turn caused outbreaks of cholera and typhoid fever.

Decentralized System.

A decentralized system refers to an on-site or clustered system used to collect wastewater from an individual lot, part of a small community, or an entire small community, and to treat and dispose of wastewater effluent in the soil (subsurface treatment and disposal). A decentralized system can include a combination of many different types of wastewater collection, treatment, and disposal methods. In times past, decentralized systems were considered to be temporary, less desirable solutions to wastewater management. However, as federal and state funds have decreased for wastewater infrastructure in the last decade and as technology has improved, decentralized systems have come to be considered a good, functional and affordable solution to wastewater issues, especially in rural communities.

On-site System. An on-site system collects, treats, and disposes wastewater typically from a single dwelling or building. The most common on-site system is a septic tank with leach field.



Construction of a typical on-site system

Decentralized System

An on-site or clustered system used to collect, treat, and disperse or reclaim wastewater from a small community or service area.

Cluster System. Cluster systems are those in which two or more dwellings may be connected to a joint subsurface treatment and disposal system. These systems may be located on public or private property. This type of multi-dwelling septic system is more suitable for small rural communities than for large, densely populated areas.

Community System. A community system is a wastewater collection and treatment system that is intermediate in scale and complexity between cluster systems and centralized systems. A community system has a collection system that collects wastewater and conveys it to a central location where subsurface treatment and discharge are utilized, though there may also be treatment in advance of the subsurface system. The treated effluent is discharged to the soil, as opposed to a wastewater treatment plant where the discharge is to surface waters. The extent and complexity of treatment of the wastewater in a community system is typically less than in a centralized system wastewater treatment plant.



*Bovina Center Community System
Town of Bovina, Delaware County
New York State*

Decentralized System Issues. In the United States, an estimated twenty five (25) percent of homes are served by decentralized wastewater systems and at least ten (10) percent of these systems might be failing annually, according to the United States Environmental Protection Agency (EPA). Thirty-seven (37) percent of new construction is served by on-site wastewater systems. In New York State, more than one and a half (1.5) million on-site systems serve over four (4) million people. The EPA identified septic systems as the second greatest threat (behind agriculture) to ground water supplies in the *National Quarter Quality Inventory: 1996 Report To Congress*.

In many New York State communities, many properties are insufficient for conventional on-site septic systems due to small lot sizes, poor soils, steep slopes, shallow depth to bedrock, existing utilities, or proximity to ground water or surface water. Age and hydraulic overloading are the most common reasons that existing septic systems fail. Failures are also caused by improper design, installation, operation, and maintenance. Common indicators of septic system failures include odors, high levels of nitrates or coliform bacteria in well water, plugged or frozen pipes, surface break-through of wastewater effluent, frequent intestinal disorders, and algal bloom and excessive plant growth in nearby ponds or lakes.

Most communities do not implement effective management programs to operate, maintain, and monitor new and existing individual on-site systems. When one or more individual system owners do not repair or maintain on-site systems until the problem is obvious and visible (such as sewage backups or septage oozing on lawns), minor problems are compounded. Serious health and environmental problems can occur when conventional on-site systems are not able to adequately mitigate nitrates, phosphorus compounds, and other contaminants. Since very few communities implement targeted monitoring to determine the level of failure of on-site systems, the actual risk that these failures pose to human health and to the environment is largely unknown.

Combined System.

In some communities, a management system that combines decentralized and centralized systems may be feasible, with centralized systems serving population centers and decentralized systems serving less populated areas.

Combined System
A management system consisting of a combination of decentralized and centralized systems in a community.

Addressing Wastewater Issues.

Decentralized systems developed a reputation for being unreliable and often were considered a poor choice when compared to centralized, well-managed systems. Now, however, with decreased government funding, with fewer acceptable sites available for infrastructure improvements, and with recent technology improvements, federal and state regulatory and funding agencies are encouraging communities to consider cost-effective solutions. Agencies are recognizing that decentralized technology is sound, and that most past problems have been associated with improper design, construction, operation and maintenance shortcomings. These agencies are now especially interested in determining the feasibility of decentralized wastewater systems. With proper design and installation, and an effective wastewater management program in place, decentralized wastewater treatment systems can be sound and cost-effective solutions to wastewater issues, especially in rural communities.

Only 1% of the earth's water is available for drinking water.

Organizational Structure and Management Programs

Many problems with on-site wastewater systems can be solved through the creation of a community wastewater organizational structure that gives the community legal authority to implement wastewater management programs.

Proper management is inherent in centralized wastewater systems. To meet federal and state budgetary and regulatory requirements, including operator staffing and management requirements, the systems must be well-organized and well-managed. A detailed description of the management structure for a centralized wastewater system is available the *Guide to Developing a Municipal Wastewater Project for Small, Rural Communities in New York State* which should be utilized as a companion document to this document.

Public policy has resulted in large, centralized wastewater systems that are effectively managed, and small, rural decentralized systems with no management at all.

Decentralized (on-site) wastewater systems are a different story. In most communities where properties have on-site septic systems, there are no community wastewater management programs. Such programs are not legally required. Homeowners typically assume responsibility for operating and maintaining individual on-site septic systems, usually with no training or experience in wastewater management. Many system failures have been linked to poor maintenance such as neglected and solids-laden tanks that result in clogged absorption fields or misuse and disturbance of areas reserved for future treatment and disposal. Examples of misuse and disturbance are planting of deep-rooted plants and trees near leach fields which may damage piping and disposal systems, or driving over these areas and impacting the soil structure.

Wastewater Management Organizational Structure

Local governments generally have the legal authority to manage centralized and decentralized (on-site) wastewater systems through the following organizational structures:

Sewer District. A town sewer district is an area of a town that will be served by a municipal wastewater system and is established pursuant to Town Law. The district ensures that the households that will benefit from the wastewater system will pay for it. Those households that are not benefited by the sewer system do not pay. Sewer districts may be comprised of a portion of a town (or a portion of a town and village within the same town, with the village's approval). Sewer districts do not have to be contiguous; they can have separate sections or areas that are not contiguous.

Ancient History
The Greeks developed dump sites around 500 BC, and in 320 BC passed the first known edict which banned refuse disposal in streets. The Greeks and later the Romans become more aware of the relationship between public health and water quality.

Different types of technologies can be used within sewer districts that implement alternative approaches to the centralized wastewater collection and treatment systems typical of larger municipalities. A district may be comprised of properties joined to a cluster treatment system, it may be comprised of multiple cluster systems, or it may be a combination of a centralized sewage system, one or more cluster systems and/or managed on-site septic systems, or any other combination. In these cases, the charges imposed within the sewer district can vary in direct proportion to the cost and benefit of the service provided.

Wastewater Disposal District or Septic Maintenance District. A wastewater disposal district or septic maintenance district provides the town with the legal authority to take responsibility for private on-site wastewater systems serving private property. According to Town Law, Article 12, Section 190-e, the town board is authorized to establish or extend a wastewater disposal district, or more than one such district, in the town, outside of any incorporated village or city, for “the purpose of administration and planning (including educational programs), design, installation, construction, rehabilitation, replacement, operation and maintenance (including pumping and inspections), monitoring, residual treatment and disposal and regulation of private on-site wastewater disposal systems of such district”. The area within the wastewater disposal district may include noncontiguous areas or properties. A wastewater disposal district cannot include any portion of a sewer district; however, a sewer district can include the maintenance of individual on-site septic systems.

Village Sewer System. The state has empowered villages to establish complete sewer systems under Village Law. Villages are able to make local improvements at village expense or to be assessed against benefited lands. A village can undertake improvements for specific areas within a village and assess the costs to those improvements against the benefited areas only. These areas are referred to as “assessment districts.”

Wastewater Management Programs

Wastewater management methods vary, from simple programs that assist homeowners with maintaining conventional on-site septic systems to a complex management program to oversee on-site wastewater system technologies that require maintenance and repair by trained operators.

The United States Environmental Protection Agency (EPA) recognizes the importance of properly managed on-site wastewater systems and offers a website, <http://cfpub.epa.gov/owm/septic/home.cfm>, specifically for on-site systems. EPA recently published the *Handbook for Managing On-site and Clustered (Decentralized) Wastewater Treatment Systems* and the *Voluntary National Guidelines for Managing On-site and Clustered (Decentralized) Wastewater Treatment Systems* to assist communities with on-site wastewater management issues.

An effective community wastewater management program should address or include the following:

- Site-specific environmental conditions
- Appropriate site-selection processes
- Codes that adapt to local site conditions and zoning/land use regulations and accommodate effective innovative and alternative technologies
- Public education and training programs
- Conservation of water
- Appropriate system design and selection processes
- Controls on operation and maintenance of systems, including residuals (septage, sewage sludge)
- Special characteristics and requirements of commercial, industrial, and large residential systems
- Compliance and enforcement programs
- Coordination with Watershed protection efforts
- Inspection, monitoring, and program evaluation components.

Ancient History

Living conditions in urban Europe became very bad resulting in widespread plague in the 12th century. As a result, changes began to take place during the 13th century. Sewage and rubbish disposal legislation began to emerge in England starting in 1372.

In addition, an effective community wastewater management program must have sufficient funding, public involvement, and support from elected officials and citizens.

EPA Voluntary National Management Guidelines

To increase the quality of management programs, the United States Environmental Protection Agency (EPA) developed the *Voluntary National Management Guidelines for Management of On-site and Clustered (Decentralized) Wastewater Treatment Systems* EPA (EPA 832-B-03-001). The Guidelines are strictly voluntary and do not substitute for any statutes and regulations. The Management Guidelines include five wastewater management models of varying levels of control. The models range from less intensive community management to more intensive community management, as follows:

Model 1 The Homeowner Awareness Model is a minimal level of management. The septic systems are still in the control and possession of the homeowner. The governing entity educates the property owners about properly maintaining a private septic system, inventories the systems within the district and reminds homeowners of maintenance at appropriate intervals.

Model 2 The Maintenance Contract Model is recommended by EPA where more complex system designs are used to enhance the treatment capacity of conventional systems or where small cluster systems are used. Because of treatment complexity, contracts with qualified technicians are needed to ensure proper and timely maintenance. This model builds on the Homeowner Awareness Model by encouraging property owners to have maintenance contracts with trained operators.

Model 3 The Operating Permit Model is recommended where sustained on-site wastewater treatment system performance is critical to protect public health and water quality. This model is appropriate in areas adjacent to lakes or water bodies, or where on-site systems have been identified as potential threats to drinking water supplies. The principal objective is to ensure that on-site systems meet their performance criteria. Permits are issued to owners for a specified time period and are renewable as long as the owner of the system demonstrates the system still complies with the permit.

Model 4 The Responsible Management Entity (RME) Operation and Maintenance Model is recommended in areas of high environmental sensitivity where there are many on-site and clustered systems. This model allows the RME to operate and maintain the decentralized system to ensure water protection even though the system is still the property of the private owner. The RME is responsible for all permits and requirements associated with the systems in a Model 4 area. In New York State, the Model 4 responsibility management entity is called a wastewater disposal district (WDD) or a septic maintenance district (SMD).

Definitions

Responsible Management Entity (RME). A legal entity established to be responsible for providing various management services with the requisite managerial, financial and technical capacity to ensure long-term management of on-site wastewater treatment systems.

--Draft Revisions. Appendix 75-A.
Wastewater Treatment Standards
Individual Household Systems
Statutory Authority: Public Health
Law, 201 (1)(1)

Model 5 The Responsible Management Entity (RME) Ownership Model requires that the treatment systems are owned, operated, and maintained by the RME. The property owner is removed from responsibility for the system although the system may still remain on the individual's property.

Conclusion. The community must determine and create the appropriate organizational structure and management program for its specific circumstances. Clearly, the choice of appropriate treatment and disposal technologies will affect the community decision on the appropriate organizational structure and management program. The process of making these decisions is reviewed in detail in the companion guidance document, the *Guide to Developing a Municipal Wastewater Project for Small Rural Communities in New York State*, mentioned in the Introduction, and available from the sponsors, funders, and authors of this manual.

More than 13 million households nationwide get their water from their own private wells and are responsible for treating and pumping the water themselves.

Basics of Wastewater Treatment

Understanding the basics of wastewater treatment processes is the first step in deciding which technology is best suited for the community or service area.

Treatment of wastewater combines various physical and biochemical processes, usually in stages which together form a “treatment train”.

Settling of solids relies on the physical tendency of some solids in suspension in water to sink. This allows for separation of solids from water in tanks. Some solids also have a physical tendency to attach to other solid surfaces such as filter media or soil particles. This allows for separation of solids from water by filtration.

Biochemical transformations are made by living micro-organisms. Many micro-organisms feed on nutrients in wastewater. These nutrients are present in either a solid form or a dissolved form. Some microorganisms feed on solid nutrients while others feed on dissolved nutrients. In the process of microbiological growth, micro-organisms form their bodies from these nutrients. These microbial bodies are insoluble solids. Biological treatment exploits this fact by using microorganisms to transform dissolved nutrients into settleable or filterable solids and then applying the physical process of settling and/or filtration in order to separate and ultimately remove them from the wastewater

Different environments foster growth for different types of micro-organism populations. Whether a conventional on-site wastewater treatment system or a more advanced treatment system, each constructed component is intended to provide a unique environment for these microorganisms.

Definitions

Absorption. The process by which one substance is taken into and included within another substance, such as the absorption of water by soil or nutrients by plants.

Aerobic. Having molecular oxygen as a part of the environment, or growing or occurring only in the presence of molecular oxygen, (as in "aerobic organisms").

Anaerobic. Characterized by the absence of molecular oxygen, or growing in the absence of molecular oxygen (as in "anaerobic organisms").

Subsurface Treatment System. An underground system for dispersing and further treating pretreated wastewater. Includes the distribution piping/ units, any media installed around or below the distribution components, the biomat at the wastewater-soil interface, and the unsaturated soil below.

Aerobic Treatment. Aerobic treatment is the process by which aerobic organisms rapidly feed on organic materials in wastewater in the presence of oxygen. When ammonia removal is required, aerobic treatment is necessary. A variety of technologies have been developed to supplement the wastewater treatment process with additional oxygen in order to accelerate treatment.

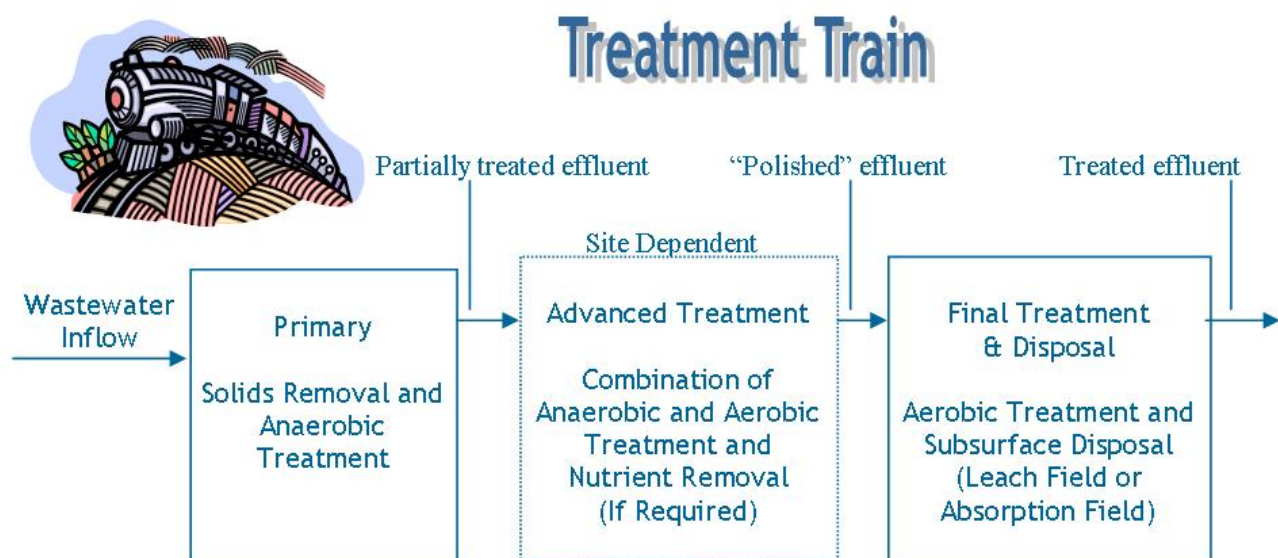
Anaerobic Treatment. Domestic wastewater contains large amounts of organic materials that provide for the rapid growth of microorganisms. Anaerobic treatment is the process by which anaerobic organisms degrade organic material without the presence of oxygen. Anaerobic treatment is much slower than aerobic treatment. The final end-products of anaerobic treatment are low molecular-weight acids and alcohols which can be further broken down anaerobically to methane. Wastewater treatment without the presence of oxygen is a relatively inefficient and incomplete process, but anaerobic treatment is effective in treating settled solids (such as waste biosolids).

Decentralized Wastewater Treatment Process - General

Treatment Train

The entire treatment process is often referred to as the “treatment train”. Generally, the treatment train can be divided into stages called primary, advanced treatment, and final treatment and disposal.

An indication of what is taking place in each treatment stage in the treatment train is provided below.



Basic Components of Wastewater

The objective of the treatment process is to remove pollutants from the wastewater. The following section describes the types of pollutants that these stages of treatment remove and how they are removed from the wastewater prior to disposing the treated effluent back to the surface or ground water.

Biochemical Oxygen Demand (BOD). Organic substances have molecules that are based on carbon. Wastewater is comprised of many varieties of organic and inorganic substances. Some examples of organic substances commonly found in wastewater include fecal matter, greases, fats, soaps, detergents, and food particles that may pass through the sink or a garbage disposal. Most common organic materials are easily decomposed by bacteria in the treatment processes. Oxygen is required for this process which breaks larger particles into smaller particles and ultimately into carbon dioxide and water. The higher the pollutant concentration in a wastewater, the more oxygen required to treat it. Biochemical Oxygen Demand (BOD) is a measure of the general strength of the wastewater and refers to the amount of oxygen required for the decomposition process. BOD is typically measured as the 5-day BOD or BOD₅. BOD₅ is the amount of oxygen consumed by the microorganisms in the wastewater during a five-day period. This is the most common measure of the amount of biodegradable organic material in the wastewater and thus is a common measure of wastewater “strength.” BOD is important to take into account when discharging treated effluent to a water body or stream because high levels of BOD can deplete oxygen in the receiving waters and have adverse effects on the ecosystem.

BOD is fairly easy to remove from wastewater as long as an adequate amount of oxygen is present to promote the healthy growth of bacteria that breaks down the organic BOD. Sewage treatment in the septic tank is anaerobic, or without oxygen. The main reason for this lack of oxygen is as wastewater enters the septic tank, it is so high in BOD that what little oxygen is present is consumed very quickly. The septic tank (primary treatment) removes some BOD through anaerobic treatment and the settling out of solids which form sludge (septage). Much of the BOD, however, passes through the primary treatment device to the rest of the treatment train where oxygen is more readily available for aerobic treatment (with oxygen), which continues to reduce BOD to acceptable levels. There are a number of treatment options discussed in future chapters that describe techniques for BOD reduction.

Total Suspended Solids (TSS). Domestic wastewater typically contains large amounts of suspended solids that are both organic and inorganic in nature. Total Suspended Solids

Pollutants of Concern

Pathogens. Parasites, bacteria, and viruses cause disease through direct or indirect contact or ingestion. They can be transported for great distances in ground water or surface waters.

Nitrogen. Excess nitrogen contributes to eutrophication and dissolved oxygen loss in surface waters. Excessive nitrate-nitrogen in drinking water can cause methemo-globinemia in infants and pregnancy complications.

Phosphorus. Excess phosphorus causes eutrophication of surface waters. This contributes to decreased oxygen levels for fish and other organisms.

-- EPA

(TSS) is a measure of these suspended solids in mg/liter or ppm of water. Septic tanks or settling tanks are designed to settle a large fraction of TSS out of the wastewater. The resulting sludge is a waste by-product that must be disposed of. Much of the Solids captured are small particles that could potentially clog small pore spaces found in filters or soil.

Phosphorus. Phosphorus in domestic wastewater is found in multiple forms. Organically bound phosphorus is a product of body and food wastes. Polyphosphates can also be found in synthetic detergents, although these products are banned in many states, including New York. Phosphorus can cause adverse effects on the environment, most notably in lakes and coastal areas where excess Phosphorus stimulates eutrophication. Eutrophication occurs when elevated levels of Phosphorus cause water bodies to become so rich in mineral and organic nutrients that plant life such as algae proliferate. After the plant life dies off, the decomposition of this organic material reduces the dissolved oxygen content in the environment and can kill off other organisms such as fish that depend on healthy oxygen levels in the water.

Total Nitrogen. Nitrogen is present in many forms in wastewater. Most nitrogen is in the form of urea and organic nitrogen (cell materials, proteins and amino acids) which is excreted by humans. Microorganisms in the septic tank break down organic nitrogen compounds fairly quickly and form ammonia. Ammonia is the primary form of nitrogen that leaves the septic tank. In the presence of oxygen (aerobic treatment), ammonia is oxidized into nitrate.

Nitrate is potentially hazardous in drinking waters and can have serious health effects on humans when present in high concentrations. Nitrate and other forms of nitrogen can also cause adverse effects on the environment, most notably in lakes and coastal areas where excess nitrogen also stimulates eutrophication. Technologies have been developed to remove the amount of total nitrogen in wastewater by converting it to nitrogen gas. This is accomplished in a two-step process called nitrification/denitrification. Nitrification is the biochemical oxidation of ammonium to nitrate. Denitrification is the biochemical reduction of nitrate or nitrite to gaseous molecular nitrogen or an oxide of nitrogen.

Overview of the Decentralized Wastewater Treatment Process; Site Evaluation

An understanding of the wastewater treatment processes will help a community choose, in participation with its engineering team and regulatory and funding agencies, the technologies or combination of technologies that are right for them. This chapter focuses on the decentralized treatment process. (A discussion of the centralized treatment process is found in Chapter 7.)

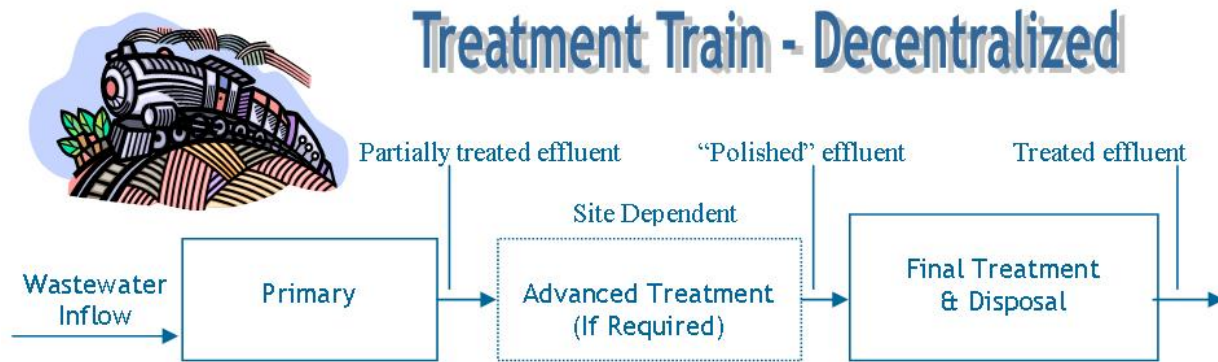
Recent History. The late 1800's brought about a widespread awareness of the correlation between disease and poorly treated wastewater. As a result, there has been a large increase in technologies over the past century. Many homes and businesses throughout the United States still utilize technologies developed at the end of the 1800's in order to treat and dispose of their wastewater. Septic tanks were being used in the late 1800's as a primary treatment device much as they are used today. Subsurface discharge of effluent in gravel-lined drains became common practice in the early to mid 1900's. Centralized wastewater collection and treatment systems have become a widespread alternative to on-site wastewater treatment and disposal systems in urban and densely-developed suburban areas, mainly due to site constraints. A number of technologies have been developed that can be applied on sites that may not necessarily have ideal conditions for the traditional septic tank and absorption field combination. These newer technologies achieve significant pollutant removal rates if the proper management oversight is employed.

Ancient History

In 3500 BC, the City of Ur had an average population density of 65,000 people per square mile. Waste was dealt with by simply sweeping it out of the dwellings and into the streets. This practice caused health problems and the need to raise house entrance elevations every so often due to the buildup of refuse.

Wastewater Treatment Process - Decentralized

On-site treatment options include physical, chemical, and biological processes that may be used alone or in combination to form a treatment train that is capable of meeting established performance requirements. The basic function of wastewater treatment is to isolate the natural water purification process from the environment and to accelerate it.



Treatment Train. There are three basic stages of decentralized treatment: primary treatment, advanced treatment, which is often optional or site dependent, and final treatment and disposal. A typical (or conventional) wastewater treatment and disposal system is comprised of a primary treatment stage and a final treatment and disposal stage. Some treatment applications may require an advanced treatment stage where a more highly treated effluent is needed prior to being sent to final treatment and disposal. There are a number of instances when advanced treatment would be required. One example is when limited space is available for final treatment and disposal where an advanced treatment stage may allow for a reduction in size of the final treatment and disposal application. An advanced treatment device may also be needed when additional nutrient removal is required, especially near environmentally sensitive areas such as lakes and streams.

Primary Treatment. Raw sewage must undergo a pretreatment stage prior to being discharged to a subsurface treatment and disposal system or advanced treatment system device. Primary treatment of wastewater refers to the physical separation of solids present in the wastewater. Physical separation is generally restricted to the natural separation of solids in the wastewater based on density. Solids that are denser than water settle to the bottom and form sludge (septage). Solids that are less dense than water such as oil and grease will float to the surface and form scum. Anaerobic treatment (without oxygen) also occurs during this stage in the treatment train. A septic tank usually provides the primary treatment for on-site wastewater treatment systems. Septic tanks and enhancements are further described in Chapters 5 and 6.

Total water use (both indoor and outdoor) in a typical single-family home is 70 to 100 gallons per capita per day (gpcd).

Final Treatment and Disposal. After wastewater has passed through the primary treatment device, and in some cases an advanced treatment device, it is not yet suitable for discharge to soil. Subsurface treatment systems are designed to provide the final treatment of wastewater

prior to disposal. An absorption field (or leach field) is often the final subsurface treatment and disposal system. An absorption or leach field provides for aerobic treatment (with oxygen). As wastewater effluent is distributed throughout the soil in the absorption field, the soil particles filter out solids that were not separated in the primary treatment stage, and due to the presence of oxygen in the soil media, aerobic microorganisms are able to thrive and form a thin layer known as a biomat on soil particles. This biomat is where aerobic treatment of dissolved pollutants occurs. Absorption fields can be constructed a number of different ways and are discussed in Chapter 5.

Advanced Treatment. Advanced treatment is employed as an intermediate stage when a more polished effluent is required. There are a number of advanced treatment technologies available, each specifically designed to remove certain pollutants from wastewater. A combination of anaerobic, aerobic, chemical, and filtering environments are available as advanced treatment processes to remove specific wastewater pollutants prior to wastewater being conveyed to the final treatment and disposal system. Advanced treatment options are discussed further in Chapter 6.

In order for the treatment train to successfully remove pollutants from wastewater, each stage of treatment must be properly designed. It is important that the location planned for an on-site wastewater treatment system is evaluated carefully. A comprehensive site and soil investigation coupled with knowledge of local rules and regulations is essential for successful treatment train design. The following sections, Site Evaluation and Soil Evaluation, outline general considerations for evaluating a site's feasibility for an on-site wastewater treatment system.

Site Evaluation for Decentralized Wastewater Treatment and Disposal

The purpose of a comprehensive site evaluation is to ensure that a site is feasible for the adequate treatment of the required volume of wastewater prior to being distributed back into the soil. Specific considerations of a preliminary site evaluation include location of nearby surface waters, utilities, terrain and surface conditions, flood zones, and local land use laws. Soil permeability and subsurface characteristics are very important when evaluating a site's suitability for a subsurface wastewater treatment and disposal system.

In addition to specific site considerations, it is important to consider the wastewater load of the service area. For example, a system that serves a single family dwelling will require a smaller area for on-site wastewater treatment and disposal than a cluster system that serves multiple dwellings.

Site Factors

There are many factors that can influence the design and/or performance of an on-site septic system. These include but are not limited to:

Lot Size. One of the most fundamental aspects of an analysis of the suitability of a site for an on-site wastewater treatment and disposal system is the area available for a septic system on a particular property. The smaller the area available for construction of a system, the less likely all other requirements can be met. In some hamlets and villages, lot sizes can be as small as 1/10th of an acre (4,000 square feet).

Set Back Limits. The state and many local communities have regulations that restrict construction within a certain distance of existing manmade and natural features such as property boundaries, wells, water bodies, aquifers, structures, top and toe of steep slopes, etc. These requirements further reduce the usable area on a property which can be used to construct a new or repair a failing on-site wastewater treatment and disposal system.

Flood Zones. Although some low lying areas appear dry most of the year, they may be subject to seasonal flooding. Sites that flood should be avoided if possible. An on-site

system may be constructed in the 100-year flood plain, if the 10-year flood elevation is lower than the lowest treatment and disposal component. A flood study may be required in order to construct an on-site wastewater treatment and disposal system near areas that are prone to flooding.

Slope Limitations. The location of a leach field is also dependent on the slope of the ground in which it will be constructed. Limitations on slopes for each type of wastewater treatment and disposal system vary depending on the type of system design and jurisdictional limits.

Geological Features. Geological features such as shallow or exposed bedrock are typically indicators of shallow soil conditions that can limit site suitability for an on-site wastewater treatment and disposal system.

Vegetation. Site vegetation may offer clues as to the type of soils, bedrock elevations, and ground water levels one can expect in the soil profile. Recognizing the types of plants that grow in wet soils can help verify ground water levels. Trees and brush that have shallow root systems may be an indication of shallow bedrock just as those with deep root systems may indicate a deeper depth to bedrock. Areas of mixed vegetation are harder to use as indicators of soil and ground water conditions, but areas with homogeneous species can be very helpful for clues about subsurface conditions.

Soil Evaluation

A thorough evaluation of the subsurface conditions is critical in determining whether or not a site is adequate for an on-site wastewater treatment and disposal system, and in designing a proper treatment and disposal system.

Soil Profile. The soil profile is a cross sectional view of subsurface conditions which gives clues as to the suitability of the soil for an on-site wastewater treatment system. One or more deep test pits are typically examined in or near the area of the expected absorption area. Deep test pits are dug with a backhoe or excavator and must be dug a minimum of five (5) feet deep or to refusal. The following factors need to be evaluated in the deep test pit:

Ground Water Elevation. Where wastewater flows into ground water, that wastewater is discharged into the environment. If sufficient treatment of the wastewater has not occurred prior to the wastewater flowing into the ground water, pollution of the ground water results. Therefore, in a subsurface treatment system, the ground water elevation is considered a depth limiting factor. A minimum of two (2) feet vertical separation is required between the bottom of the absorption trench and the top of the seasonally high ground water elevation. This area is called the treatment zone. In New York State, the minimum depth of the treatment zone is two (2) feet, with deeper treatment zones being more desirable and sometimes required. The ground water elevation partially determines the feasibility of a site for treatment and disposal of wastewaters. Seasonal weather variations affect ground water levels. In New York State, heavy spring rains

and annual snow melt markedly raise ground water levels, typically between March 15 and June 30. Ground water levels are also affected by flooding and times of drought.

Soil color can be a useful indicator of seasonally high ground water levels. Uniform brownish colored soil typically indicates aerobic and chemically oxidizing conditions. Splotches of gray and yellow or uniform gray colors often indicate saturated conditions beneath the seasonal high ground water table. This is called mottling. Ground water can be monitored with shallow monitoring wells or by observing standing water in deep test pits. Due to the many variations in soil types and colorations, mottling can be difficult to identify, and often a trained soil scientist is needed.

Bedrock or Restrictive Layer. Absorption field sites are required to have a certain depth of usable soil below the bottom of the trench or bed. The restrictive layer elevation is considered a depth limiting factor and must be evaluated in order to determine the feasibility of a site for treatment and disposal of wastewaters. A restrictive layer can be bedrock, layers of tightly packed impermeable soils such as clay, shale layers, etc. These layers, if present, need to be located during the deep test pit inspection. Dense substrata such as shale, fragipan, argillite, clay, and cemented limestone restrict the vertical movement of wastewater. On the other hand, fractured or channeled rock underlying a shallow soil profile may facilitate the horizontal movement of untreated wastewater, which in turn could contaminate groundwater, nearby wells, and surface waters.

Soil Percolation (Perc Test). The rate at which water will flow through a soil is its hydraulic conductivity. Hydraulic conductivity in the area planned for the absorption area is estimated by measurements called soil percolation tests (perc tests). Soil types like clay have very slow percolation rates and can therefore be unsuitable for conventional septic systems. Extremely fast percolation rates are also undesirable because insufficient treatment is provided before the effluent reaches the ground water.

In general, a 12" diameter percolation test hole is typically excavated at the depth of the proposed absorption system (24" for a conventional system). The percolation rate is determined by measuring the amount of time it takes for water to drop one inch, from six inches to five inches, in the test hole. Multiple tests are performed until consecutive time trial readings are close to each other. Acceptable results depend on the type of absorption system being planned and on local regulations, but typically range between two (2) or three (3) minutes and sixty (60) minutes. Percolation rates less than one (1) minute are too fast and are unacceptable for final treatment and disposal. Sites with soils that have fast percolation rates have faster soil hydraulic conductivity than sites with slow percolation rates. For example, a 5 min/inch (fast) percolation rate will require a smaller absorption system than a 50 min/inch (slow) percolation rate. Design measures for dealing with soil percolation results that are too fast or too slow are described in Chapter 6 of this manual.

Texture and Structure of Soil Layers. The nature of the soils found when examining the soil profile is an important factor in determining the effectiveness of the soils in the

treatment of wastewater. Soil texture is the relative proportions of the various soil separates (silt, clay, sand) in a soil. Soil structure is a tendency of soil in its natural state, whether dry or moist, to form aggregates of a definite shape resembling a geometric figure. Soil may have a prismatic, block, granular, or platy (flat) structure which may indicate certain drainage characteristics, and this can be used to determine limits of soil layers. Because of variations in structure, soils of the same texture may have widely different percolation rates.

Soils with high clay content do not percolate as well as those with high sand content. While soils with a high clay content may not be suitable due to an inadequate passage of liquids, soils with high sand content may percolate too rapidly and not provide enough treatment prior to wastewater effluent being disposed back into the ground water. In general, soils with coarse soil particles have a faster percolation rate than those with very fine particles. The basic categories of soil texture and a brief description of how to identify each follows.

Sand. Individual grains can be seen and felt readily. Squeezed in the hand when dry, this soil will fall apart when the pressure is released. Squeezed when moist, it will form a cast that will hold when the pressure is released but will crumble when touched.

Sandy Loam. Consists largely of sand, but has enough silt and clay present to give it a small amount of stability. Individual sand grains can be seen and felt readily. Squeezed in the hand when dry, this soil will fall apart when the pressure is released. Squeezed in the hand when moist, it forms a cast that will not only hold its shape when pressure is released, but will withstand careful handling without breaking. The stability of the moist cast differentiates this soil from sand.

Loam. Consists of an even mixture of the different sizes of sand and silt and clay. It is easily crumbled when dry and has a slightly gritty, yet fairly smooth feel. It is slightly plastic. Squeezed in the hand when dry, it will form a cast that will withstand careful handling. The cast formed of moist soil can be handled freely without breaking.

Silt Loam. Consists of a moderate amount of fine grades of sand, a small amount of clay, and a large quantity of silt particles. Lumps in a dry undisturbed state appear quite cloddy but they can be pulverized readily; the soil then feels soft and floury. Either dry or moist casts can be handled freely without breaking. When a ball of moist soil is pressed between thumb and finger, it will not press out into a smooth, unbroken ribbon but will have a broken appearance.

Clay Loam. A fine textured soil which breaks into clods or lumps that are hard when dry. When a ball of moist soil is pressed between thumb and finger, it will form a thin ribbon that will break readily, barely sustaining its own weight.

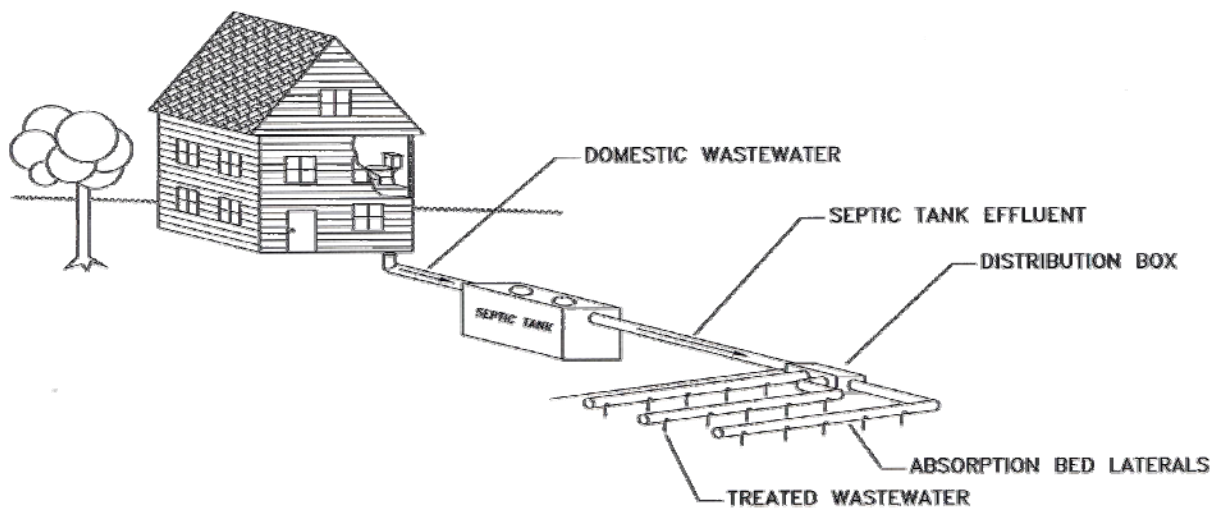
The moist soil is plastic and will form a cast that will withstand considerable handling.

Clay. A fine-textured soil that breaks into very hard clods or lumps when dry, and is plastic and usually sticky when wet. When a ball of moist soil is pressed between the thumb and finger, it will form a long ribbon.

Decentralized System Technology Options

Recognizing the many types of treatment technologies will help a community decide which options to choose in developing the appropriate system. The decentralized treatment options described in this chapter are currently the most widely accepted in the industry and will provide options from which the community and their Engineer may select when considering a community wastewater treatment system.

As discussed in Chapter 4, there are three basic steps in the decentralized treatment process: primary treatment, final treatment and disposal, and advanced treatment. Advanced treatment is an optional step that may be required based on site and soil characteristics and local requirements. Advanced treatment options will be visited in Chapter 6. It is important to note that the options outlined below represent the most widely accepted practices in New York State.



Primary Treatment



Primary treatment of wastewater refers to the physical separation of solids present in the wastewater. Physical separation is generally restricted to the natural separation of solids in the wastewater based on density. Solids that are denser than water settle to the bottom and form sludge. Solids that are less dense than water, such as oil and grease, float to the surface and form scum. Primarily physical solids separation and anaerobic treatment occurs during this stage in the treatment train. Septic tanks provide pretreatment in most decentralized systems.

Septic Tanks. Septic tanks are generally buried watertight containers typically constructed from concrete, polyethylene, fiberglass, and in some cases steel. Septic tanks are designed with inlet and outlet sanitary tees, or an interior baffle(s) which insure the formation and retention of sludge and scum within the tank in order to prevent clogging of the (downstream) subsurface treatment and disposal system, or of an advanced treatment system, if one is being used.

Ancient History
The septic tank was invented in 1860 by Louis Moureas. Early septic tanks were large and designed to treat community wastewater. This was the first conscious step taken to remove solids from wastewater prior to discharging to streams and water bodies. Effluent was still largely untreated and water pollution continued to be a health issue. It became apparent that additional wastewater treatment was needed in addition to the septic tank.

In addition to the separation of solids, septic tanks promote digestion and decomposition of organic matter in an anaerobic environment. Anaerobic bacteria can reduce retained organic molecules to soluble compounds and gases. Low rate Anaerobic treatment is a natural process that can significantly reduce the sludge volume in the septic tank as long as the environment promotes the healthy growth of anaerobic bacteria. The sludge and scum volumes build up in the tank, so the septic tank scum and sludge (septage) must be removed periodically, usually every three (3) years, sometimes more often. This sludge is typically transported to a centralized wastewater treatment plant.

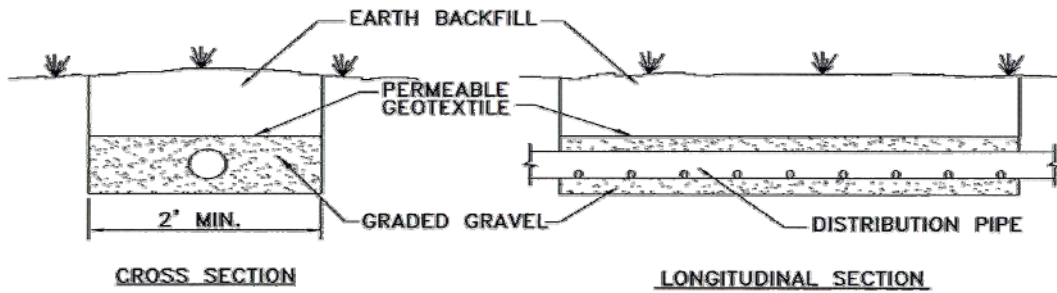
Final Treatment and Disposal (Subsurface Treatment and Disposal Systems)



After wastewater has passed through a primary treatment device, it is not yet suitable for direct discharge to surface waters or ground water. Subsurface treatment and disposal systems are designed to provide final treatment and disposal of wastewater. An absorption field (also called a leach field) can be constructed in a number of different ways. The type of absorption field for any given use depends on site and soil characteristics as well as local land use ordinances. It is important to understand that although absorption fields are constructed differently depending on site and soil characteristics, they are all designed under local and state requirements in order to reach the same treatment goals. The descriptions given below for each type of absorption field include general criteria used to choose an acceptable design. These general applications can be modified slightly to accommodate each site and the population being served. This is the project professional engineer's responsibility.

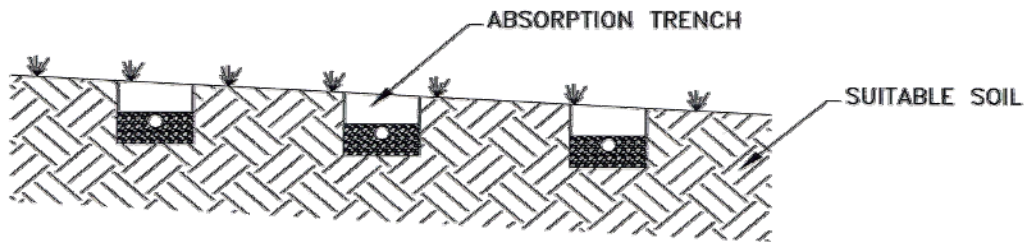
Sufficient amount of air exchange in the soil is necessary to promote aerobic (oxygenated) growth of organisms in the absorption field, and sufficient time and soil contact is also necessary for proper filtration of the effluent before it reaches the ground water table. The size of the absorption field depends on the area needed to properly distribute the effluent into the ground. This is based on the percolation rate of the soil and the rate of sewage produced by the occupants of the area being served.

Absorption Trenches. Conventional absorption trenches are narrow excavated trenches that are approximately two (2) feet deep and two (2) feet wide. They are partially filled with a bed of washed gravel or crushed stone through which a perforated pipe (or lateral) is laid. The trench is then backfilled with soil and seeded. All absorption trenches are constructed parallel to ground contours so that they can be laid nearly level. Septic tank effluent or advanced treatment effluent is conveyed by buried pipes to a distribution box which evenly distributes the effluent to the absorption trenches. The effluent seeps out of the perforated pipes and into the gravel bedding and the soil beneath, where aerobic treatment and physical separation of solids in the soil occur.



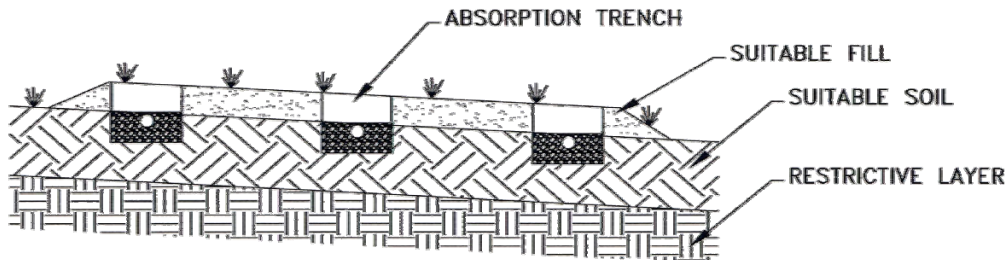
ABSORPTION TRENCH

Conventional absorption trenches are typically used when there are four (4) or more feet of suitable soil conditions. Other soil conditions may alter the depth of the absorption trenches. In these cases, the pipe and bedding construction remain similar to a conventional absorption trench although the depth of the trench is deeper or shallower depending on subsurface conditions. Absorption trench options may be further regulated in their use and construction by local regulations.



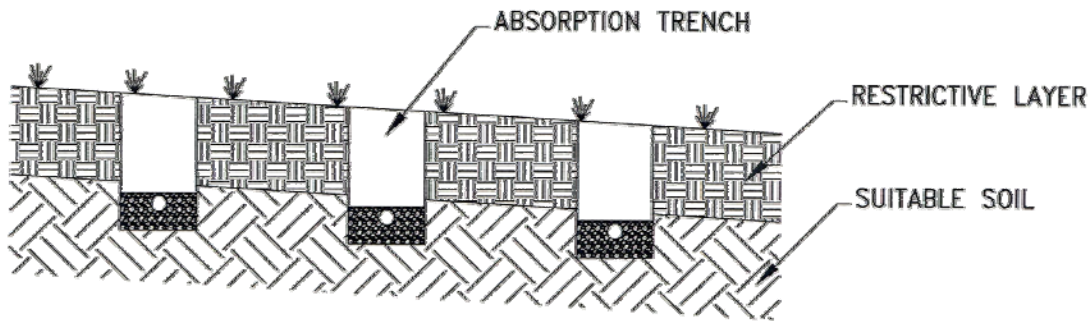
CONVENTIONAL ABSORPTION TRENCH

Shallow absorption trenches are typically used on sites with at least two (2) feet of suitable soil but less than four (4) feet of suitable soil.



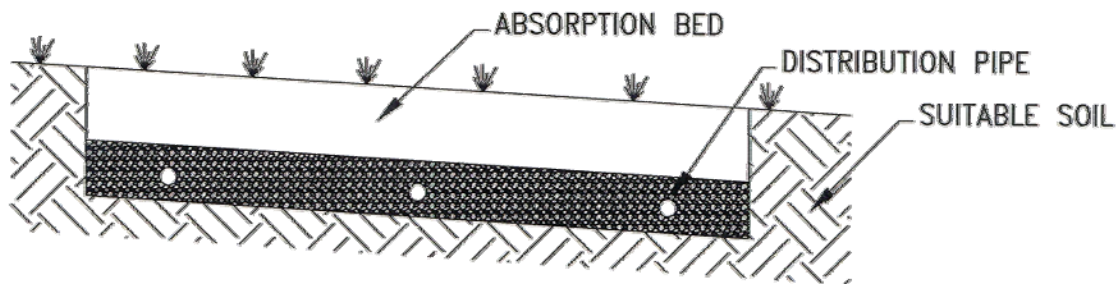
SHALLOW ABSORPTION TRENCH

Deep absorption trenches are typically used on sites when at least four (4) feet of suitable soil is overlain by one (1) to five (5) feet of unsuitable soil.



DEEP ABSORPTION TRENCH

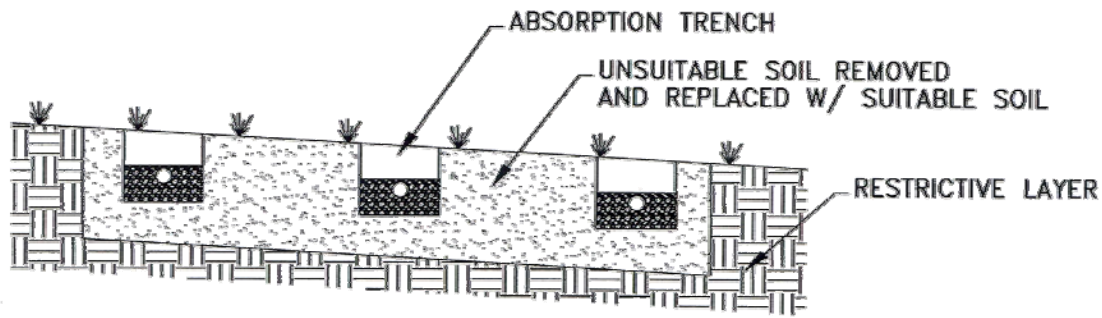
Absorption Bed. Absorption beds are similar to absorption trenches except several laterals are laid in a single excavation that is filled with a bed of washed gravel or crushed stone. Absorption beds are typically used on sites that are limited by the area available for a conventional leach field. An absorption bed is typically less desirable than an absorption trench due to the reduced sidewall area, which is the undisturbed soil surrounding the trench or the bed.



ABSORPTION BED

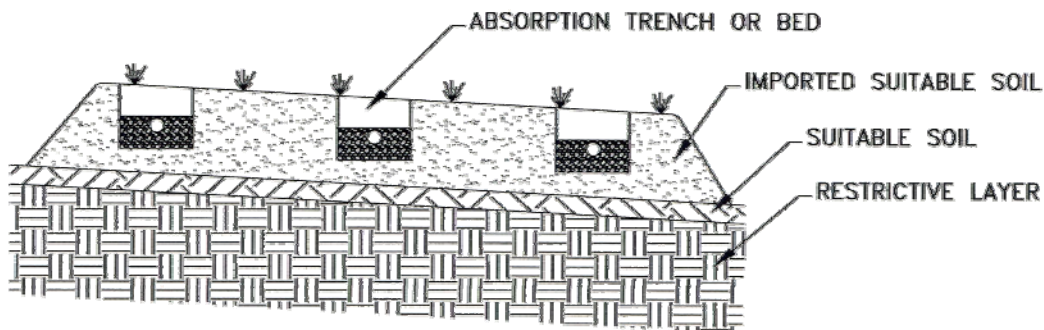
Gravelless Absorption System. Gravelless absorption systems are typically pre-manufactured products which provide infiltration to the soil in the absence of washed gravel or crushed stone. Gravelless absorption trenches are typically used when aggregate is not readily available or constructing a conventional absorption trench is not feasible due to site constraints. Typical products are constructed of a perforated plastic pipe structure and/or a permeable plastic media wrapped with permeable geotextile.

Cut and Fill System. Cut and fill systems are typically used either on sites with one (1) to five (5) feet of relatively impermeable soil or on sites with soils that have relatively fast percolation rates (faster than the jurisdictional permitting authority will allow). The unsuitable soil is excavated and removed with care to the depth of the permeable lower strata so as not to compact the lower strata. The excavated area is filled with suitable soil so that absorption trenches can be installed.



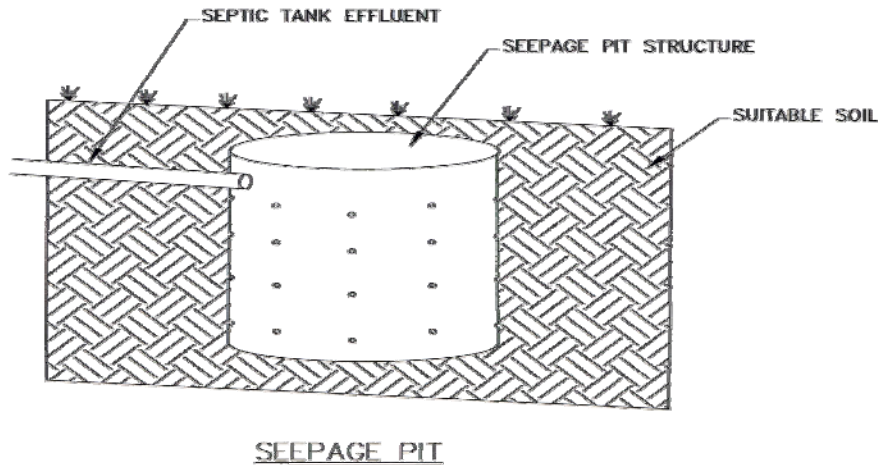
CUT AND FILL SYSTEM

Raised Bed and Mound System. Raised bed and mound systems are comprised of an absorption field which is installed in stabilized permeable fill that is placed above the original ground surface. Raised systems are constructed on sites that have at least one (1) foot but less than two (2) feet of moderately permeable soils. Some local regulators may not allow raised beds or mound systems.



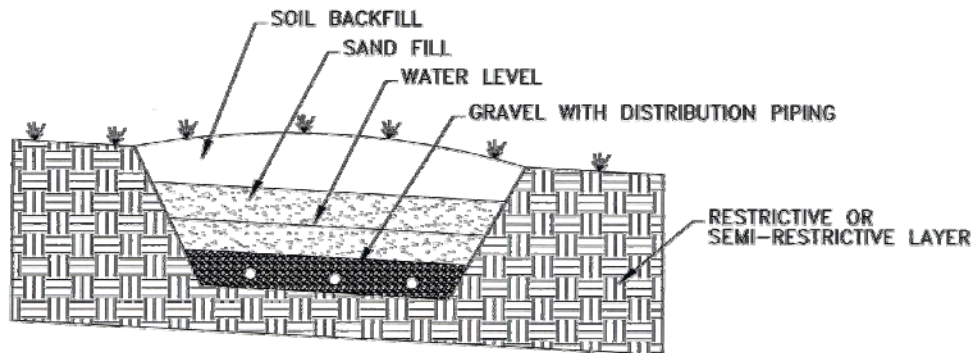
RAISED SYSTEM

Seepage Pits. Seepage pits are buried structures with a perforated or permeable lining through which wastewater effluent passes through and infiltrates into the surrounding soils. Seepage pits are typically used on sites that have a limited area where construction of an absorption field is not feasible. Absorption fields provide better distribution and treatment of wastewater effluent than seepage pits. Successful seepage pit installation typically requires deep and moderately permeable soils.



Evaporation-Transpiration (ET) & Evapo-Transpiration Absorption (ETA) Systems.

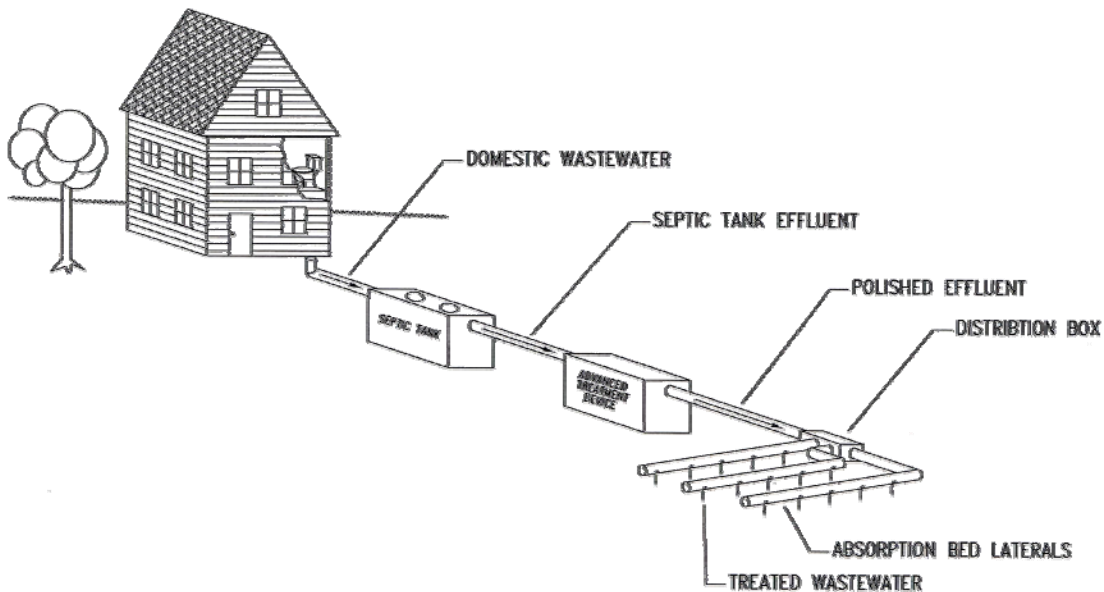
Evaporation-transpiration (ET) systems rely on the upward movement of moisture through the soil, evaporation into the atmosphere, surface vegetation, and transpiration as the disposal methods. Evapo-transpiration absorption (ETA) systems use a combination of the above actions and subsurface absorption in order to dispose of treated wastewater. These systems are typically constructed only in arid to semi-arid climates because excess precipitation tends to saturate the upper soil strata or soil layers and overload the systems causing them to fail. However, these types of systems have been successful in New York State for seasonal dwellings which utilize the system only during the summer months.



Chapter Summary. The treatment options described in this chapter cover widely accepted methods for primary treatment and final treatment and disposal. Depending on site and soil characteristics, each site will use one of the treatment methods for each treatment stage. In some instances, again depending on site and soil characteristics and local requirements, a more polished effluent is desired. This is when advanced treatment options are explored. These are sometimes called treatment enhancements.

Decentralized Treatment System Enhancements

Enhanced treatment options described in this chapter may be necessary to supplement basic treatment methods when a more polished effluent is required.



Septic Tank Enhancements



There are a number of methods to enhance the quality of typical treatment levels or introduce additional types of treatment in the septic tank. Septic tank enhancements are typically used

when a more polished effluent is required. Multiple methods may be used in the same application in order to compliment each other and further increase treatment efficiency.

Aeration. Aeration involves introducing oxygen (via air compressor(s), blowers, or mechanical mixing) to wastewater in the septic tank in order to provide an oxygen rich environment for aerobic organisms. Aeration treatment enhancements typically use a mechanism to inject and circulate air within the wastewater. Oxygen introduced directly to wastewater during primary treatment stimulates the growth of aerobic bacteria which promotes improved biological decomposition of organic material. Aerobic digestion breaks down organics in the wastewater at a faster rate than anaerobic digestion. This reduces BOD₅ levels during the primary treatment stage and creates a more polished effluent.

Engineered aerobic biological treatment devices have been available for a few decades. These pre-engineered units generally replace the septic tank and typically have a combination of aeration and effluent filtering enhancements after solids removal. These treatment devices provide an oxygen rich environment that promotes aerobic treatment as opposed to the conventional septic tank that utilizes anaerobic treatment of wastewater. A similar environment can also be provided in a conventional septic tank with an aeration and effluent filtering device.

Effluent Filters. Septic tank effluent is relatively clear of large particles but still contains small suspended solids that are passed on to the next stage of the treatment train. Over time, these suspended solids can build up, clogging pore spaces in the absorption field and ultimately reducing the longevity of the system. One method of decreasing the suspended solids that are passed from the septic tank is to provide an effluent filter. There are a variety of effluent filters that are all unique in design but similar in purpose. They all reduce the amount of small suspended solids that are passed to the rest of the treatment train. The reduction in solids not only reduces TSS from the septic tank effluent but also BOD₅ due to the decrease in organic particles, and promotes leach field longevity.

Inoculators. There are a number of devices available that continuously inoculate the septic tank with cultures of bacteria which promote aerobic treatment in the septic tank when paired with an aeration device. The introduction of aerobic treatment in this manner is typically used to accelerate BOD₅ removal.

Advanced Treatment Enhancements

Advanced treatment is considered in the construction of a decentralized wastewater treatment system when a more polished effluent is desired, or where basic wastewater treatment methods may not suffice. The type of treatment used is determined by site-specific needs and/or local jurisdictional requirements. There are a number of instances when this additional step in the treatment process may be warranted, including, but not limited to:

- sites that are near environmentally sensitive areas such as lakes and streams which may benefit from increased nutrient removal to prevent eutrophication

- sites that are limited in available area for a treatment system, creating a need to reduce the size of the final treatment and disposal system by first polishing the wastewater effluent
- as an add-on to an existing system that is partially failing and would benefit from a more polished effluent.

Advanced Treatment Systems or Devices

There are many versions of each of the advanced treatment methods described below. These are general descriptions of applications that are in wide use today.



Intermittent Sand Filtration. Intermittent sand filtration is an aerobic treatment system that utilizes a bed of carefully graded media that is drained from underneath so that wastewater can be filtered, collected and distributed to a final treatment and disposal system. Sand is a commonly used media although anthracite, mineral tailings, glass and ash have been used as a substitute. Intermittent sand filters remove contaminants through physical, chemical, and biological treatment processes. Sand filters are normally used to further treat effluent from a septic tank before being distributed to final treatment and disposal.

Bio-Filters. Bio-filters remove contaminants through physical, chemical, and biological treatment processes. Bio-filters are typically pre-engineered systems. A number of different types of media can be used including peat, foam, textile, and tire chips. Peat is the most common media used and, much like the sand filter, is used to polish effluent from a septic tank before being distributed to final treatment and disposal.

In 1868 Edward Frankland developed the first trickling sand filter technology which was further developed by the Massachusetts State Board of Health at their experimental station in Lawrence Massachusetts in 1893.

Trickling Filters. Trickling filters are aerobic treatment systems that utilize microorganisms attached to media to remove organic matter from wastewater. This system is known as an attached growth (or fixed film) process and can be used to polish effluent from the septic tank before being discharged to a subsurface treatment and disposal system. Microorganisms in the wastewater attach themselves to the filter media as they flow through it and form a biological film or slime layer. The organic material from the wastewater is degraded by the aerobic microorganisms in the outer part of the slime layer. As the biological film grows and becomes thicker, the inner portions of the slime layer are starved of oxygen and organic carbon and as a result fall off the filter media in a process called sloughing. Typically a settling basin (or clarifier) is used for separation of the sloughed solids which are pumped back to the septic tank for removal.

Wetlands and Aquatic Plant Systems. A wetland and aquatic plant system is an artificial ecosystem designed to be used as a functional part of wastewater treatment. Wastewater can be treated in the wetland environment, collected and distributed to a final treatment and disposal system.

Aquatic systems primarily treat wastewater by means of microbial treatment and physical sedimentation. The plants in an aquatic system bring about little actual treatment of wastewater, but they do support the necessary components of the treatment environment. The roots and stems of the plants that are submerged in water provide a media for filtration and adsorption of solids as well as providing a surface for microbes to grow. The stems and leaves which are at or above the water surface help prevent the growth of algae by blocking sunlight, controlling the amount of gas transfer between the atmosphere and water by reducing the effects of wind, and facilitating the transfer of gases to and from the submerged parts of the plant.

It is important to note that there are many different types of wetland plantings and environments that can be used for an aquatic plant system. Plantings will vary depending on the local climate and type of wetland environment that is available or desired. It is also important to note that there tends to be more regulatory roadblocks when permitting wetlands and aquatic plant systems due to the dynamic nature of these systems.

Enhanced Nutrient Removal (Phosphorus and Nitrogen). There are many advanced treatment processes that can reduce nitrogen and a few that can reduce phosphorus. Most phosphorus removal processes are enhancements to other treatment processes that increase the overall removal of phosphorus.

Phosphorus Removal Devices. The removal of phosphorus is of concern where effluent may enter surface waters via subsurface flow through fractured bedrock, or in poor soils where little phosphorus exchange would occur. Phosphorus is a key element in the eutrophication of water bodies.

Most aerobic treatment systems, including absorption fields, have the natural ability to remove 10 to 20 percent of the influent phosphorus. The use of phosphate-free detergents, which has become common practice in many states, has also contributed to the reduction of phosphorous loading in wastewater

Phosphorus removal processes generally fall into the categories of chemical, physical, and biological systems. Most notable successes have come with special-engineered materials that are naturally high in chemicals such as aluminum, iron, and calcium compounds, but their service lives are limited. Studies indicate that 50 to 95 percent of the phosphorus can be removed by filtration using a sand media with high iron content. Other sands with high concentrations of aluminum, iron, and calcium compounds will exhibit high phosphorus removal rates for a limited amount of time. These types of media filters are most common for community systems.

Alternatively, a solution of iron or aluminum salts can be fed into the wastewater to precipitate phosphorous compounds which can then be removed by settling or filtration or both.

Nitrogen Removal Devices. Nitrogen in ammonia form is toxic to certain aquatic organisms. Ammonia is oxidized rapidly to nitrate in the environment, creating a higher oxygen demand and lower dissolved oxygen levels in surface waters. Organic and inorganic forms of nitrogen can cause eutrophication. High concentrations of nitrate can harm unborn children and young children when ingested. The most common and effective method of nitrogen-removal is the nitrification-denitrification process.

Ammonia oxidation (nitrification) is dependent upon oxygen availability, organic biochemical oxygen demand (BOD_5), and hydraulic loading rates. Nitrogen removal by means of volatilization, sedimentation, and denitrification may also occur in some of the systems and system components. The amount of nitrogen removed is dependent upon process design and operation. Processes that remove 25 to 50 percent of the total nitrogen include aerobic biological systems and media filters, especially recirculating filters.

The vast majority of practical nitrogen-removal systems employ nitrification and denitrification biological reactions. Most notable of these are recirculating sand filters, and an array of aerobic nitrification processes combined with an anaerobic process to perform denitrification. Some of these combinations are proprietary. Any fixed-film or suspended-growth aerobic treatment device can perform the aerobic nitrification when properly loaded and oxygenated.

Overview of the Centralized Wastewater Treatment System Process and Technology Options

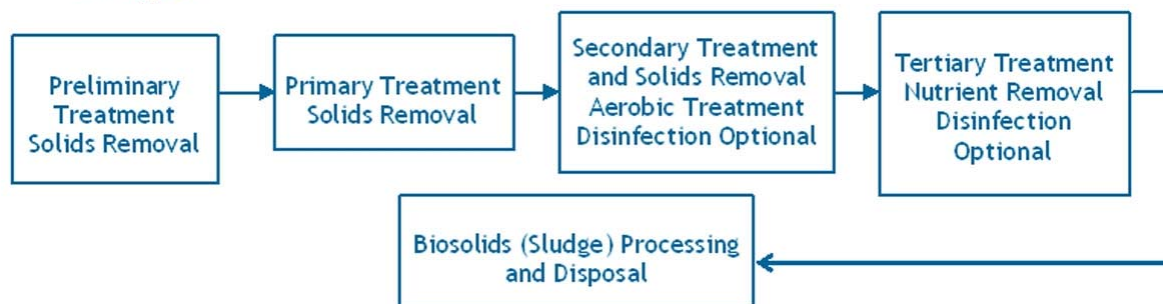
A centralized wastewater collection and treatment system is often used in densely populated areas where site constraints do not allow the use of septic systems or other decentralized systems. This chapter provides an overview of the centralized treatment process and an introduction to the most common technology options currently available.

Wastewater Treatment Process - Centralized

The purpose of a treatment system is to produce a clean treated effluent suitable for discharge back into the environment. Wastewater treatment incorporates physical, chemical and biological processes which remove physical, chemical and biological contaminants from a community's wastewater. Sludge (or biosolids), which is the solid waste byproduct associated with wastewater treatment, is disposed of or beneficially reused.



Treatment Train - Centralized



Treatment Train. Centralized wastewater treatment facilities typically consist of pretreatment, primary treatment, and secondary treatment. Sometimes tertiary or advanced treatment is also necessary.

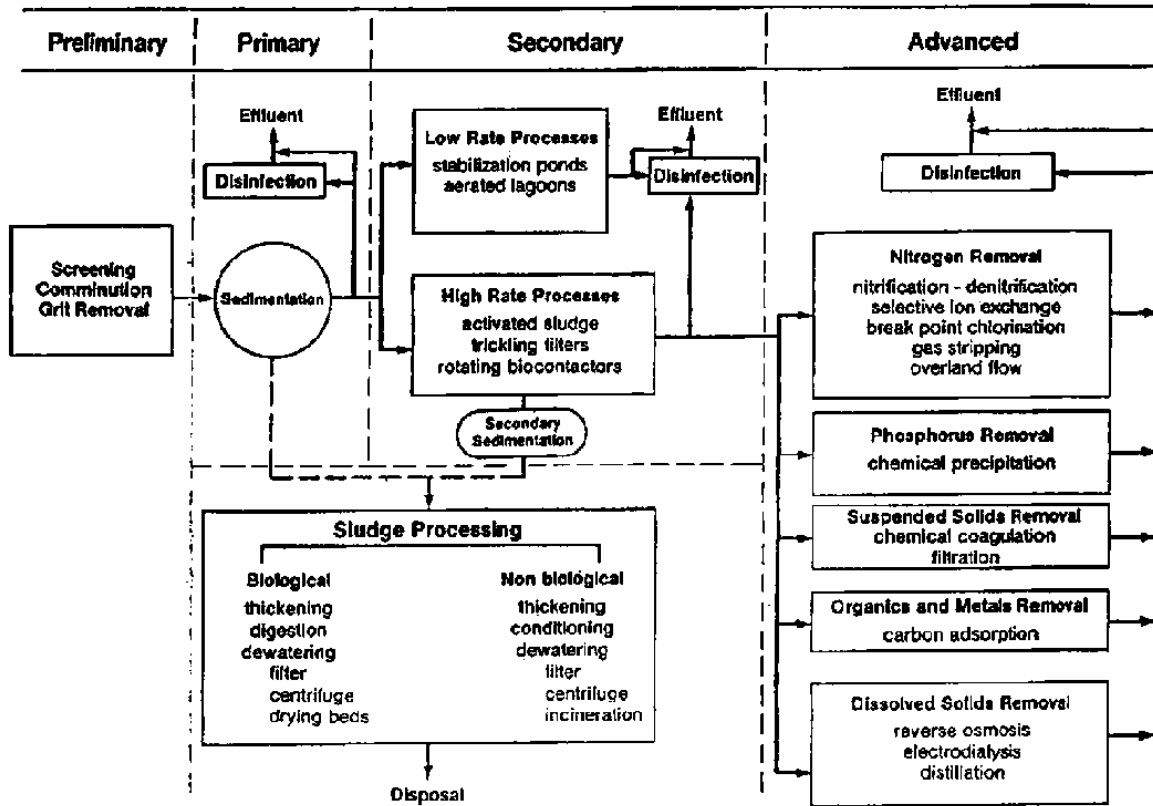
Preliminary Treatment. Typical municipal sewer systems consist of a collection system that carries wastewater to a central treatment facility for treatment and disposal. At the plant, wastewater first flows through a screen and/or comminutor/grinder that reduces and removes large floating objects. Wastewater then usually passes into a grit chamber where sand, small stones, and other heavy settleable solids are removed.

Primary. Settleable solids are collected at the bottom of a settling tank and form a mass of solids called primary sludge. The biosolids are separated and either combined with secondary settling, or removed and further treated to be used as fertilizer, disposed of in a landfill, or incinerated.

Secondary. Secondary treatment is used in many communities. The secondary stage is typically a method that uses bacteria to remove organic matter from the sewage and reduce BOD₅. This is also referred to as biological treatment. Secondary treatment also includes a settling component to separate biosolids created by the biological process. Many times, the final step in secondary treatment is disinfecting the effluent with chlorine, ozone or ultraviolet light before it is discharged into the receiving waters. If chlorine is used in the process, dechlorination may be required prior to discharge to surface waters.

Historically, water was considered clean if it was clear. Hippocrates, the Father of Medicine, invented the "Hippocrates Sleeve", a cloth bag to strain rainwater, in the 5th century B.C.

The following is a general flow diagram for a centralized wastewater treatment process:



From *Wastewater Treatment and Use in Agriculture Irrigation and Drainage Paper 47*, by M.B. Pescod, Food and Agriculture Organization of the United Nations, 1992.

Centralized System Technology Options

There are many centralized treatment technologies available; those described in this chapter are currently the most widely accepted in the industry.

Preliminary Treatment.

When wastewater reaches the treatment plant via the collection system it contains large solids and grit which typically should be removed so as not to interfere with the treatment process or cause undue stress and maintenance on the wastewater treatment components. Grit is more common in older collection systems where soil particles migrate through pipe joints. Screening, comminuting (grinding), and grit removal are the most common preliminary treatment processes in a centralized system. Two other functions that are considered to be associated with the preliminary treatment stage are septage handling and flow equalization to the plant, if provided.

Screening. The first step in the preliminary treatment process is screening. Screening is typically accomplished by directing the incoming wastewater through a bar screen

configuration which separates large solids in the wastewater such as rags, plastic, wood, and any other foreign debris that may have found their way into the collection system. Coarse screens with openings of 1"- 4" are intended to separate larger debris, while screens with smaller openings are intended to separate smaller suspended solids which may create operational and maintenance problems with the process equipment. Fine screens less than one inch can provide reduction of settleable solids close to that of primary clarification (see primary treatment, below); however, the solid waste stream from the headworks also increases.

Comminution. Comminutors and grinders can be used to process coarse solids and reduce their size before passing them on to downstream treatment facilities. Solids are reduced to ¼" to ¾" in size. Comminutors are comprised of a rotating cylinder with slots in it. Solids which are too large get trapped and are cut by blades as the cylinder rotates. Once reduced in size, these solids are able to be passed on to the next process. Grinders are comprised of two counter-rotating cutters which are intermeshed. The cutters reduce debris size as they rotate and pass the smaller particles on to the next process.

Grit Removal. Grit removal typically follows screening and comminution. Grit includes all solids in the wastewater that have settled out near the bottom of the incoming waste. Grit includes but is not limited to sand, gravel, eggshells, bone, coffee grounds, etc. These solids, if not removed, have the ability to cause undue wear and damage to downstream treatment facilities. There are a number of grit removal systems such as aerated grit chambers, vortex systems, sediment basins, velocity controlled channels, and cyclonic inertial separation devices. Each grit removal method has its advantages and disadvantages depending on the configuration of the treatment facility and the quantity and characteristics of the grit.

Primary Treatment

Primary treatment typically consists of a settling or sedimentation stage where wastewater is passed through large circular or rectangular tanks where the wastewater is allowed to flow slowly for up to a few hours. These structures are typically referred to as primary clarifiers. Organic and inorganic solids settle to the bottom or float to the surface. The purpose of the sedimentation process is to produce a generally homogeneous liquid for further biological treatment and a sludge that can be separated and removed for further treatment. Sedimentation also results in BOD and TSS reduction. Primary clarifiers are typically equipped with mechanical scrapers and skimmers that drive the settled sludge towards a hopper in the bottom of the tank, and scrape floatable scum from the top. Sludge and scum are pumped to sludge treatment facilities before final disposal.

Secondary Treatment

Secondary treatment is intended to reduce the oxygen demand and nutrient levels of the wastewater significantly. Generally, secondary treatment is accomplished in an oxygen rich (aerobic) environment which promotes a less pungent, oxidized effluent. Microbes consume biodegradable soluble organic contaminants in the wastewater such as fats, sugars, and organic short chain carbon molecules. In order for this process to be successful, the microbes require oxygen and a substrate on which to live. Attached growth (fixed film), and suspended growth

systems are used to provide this type of environment. The processes differ primarily in the manner in which oxygen is provided for the microorganisms and in the rate at which the organic matter is metabolized. These systems are designed so that enough of the impurities will be removed to prevent significant oxygen demand in receiving waters which can cause adverse impacts to the ecosystem of the receiving water body.

High rate processes consist of relatively low volume reactors with high concentrations of microorganisms. Low rate processes consist of a well controlled environment. The growth rate of organisms is much greater in high rate processes. Microorganisms are subsequently separated from the treated effluent by sedimentation in tanks typically referred to as secondary clarifiers. The sludge removed during this stage of treatment is typically combined with the primary sludge and then processed further. Common high-rate processes include the activated sludge processes, trickling filters, and rotating biological contactors (RBC).

Activated Sludge Process. In this process, aeration tanks are mixed vigorously with oxygen (aerated) and microbe-laden wastewater that can be described as a mixed microbial culture. Typical aeration devices include submerged diffusers which release compressed air and mechanical surface aerators that introduce air to the wastewater by agitating the liquid surface. After a period of aeration, the microbe-laden wastewater is allowed to settle for a number of hours. The microorganisms are separated from the liquid by sedimentation and the clarified liquid is called secondary effluent. A portion of the biomass is returned to the aeration basin to maintain a high population of micro-organisms – this is called return sludge. The remainder is removed from the process and sent to sludge processing – this is called waste sludge. Several variations of the basic activated sludge process are in common use, but the principles are similar.

Trickling Filters. Aerobic treatment systems that utilize microorganisms attached to a media to remove organic matter from wastewater are known as attached growth or fixed film processes. Common media used in trickling filters include stones, plastic, foam, or wooden slats. Oxygen is typically supplied to the biofilm by the natural flow of air either up or down through the media. Microorganisms in the wastewater attach themselves to the filter medium as they flow through it and form a biological film or slime layer. The organic material from the wastewater is degraded by the aerobic microorganisms in the outer part of the slime layer. As the biological film grows and becomes thicker, the inner portions of the slime layer are starved of oxygen and organic carbon and, as a result, fall off the filter media in a process called sloughing. The sloughed solids are separated from the wastewater effluent in a secondary clarifier and discharged to sludge processing. Wastewater effluent from the secondary clarifier is referred to as secondary effluent, and a portion is often recycled to the biofilter to improve and control hydraulic distribution of the wastewater over the filter media.

Rotating Biological Contactors (RBCs). RBCs are a fixed-film process similar to trickling filters in that microorganisms are attached to support media. RBCs have slowly rotating discs that are partially submerged in flowing wastewater. Microorganisms attach themselves to the rotating media and are mechanically rotated through the wastewater. Oxygen is supplied to the attached biofilm from the air when the discs are raised out of the water. Since the wastewater becomes slightly aerated by the turbulence created by the rotating discs, oxygen is also

supplied to the biofilm from the liquid when the biomass is submerged. Sloughed pieces of biomass are removed by secondary clarifiers in the same manner described for trickling filters.

Sand/Media Filters Intermittent Sand/Media Filters are aerobic, fixed film bioreactors. Sand filters also provide physical treatment such as straining and sedimentation of wastewater effluent. Sand filtration is an aerobic treatment system that utilizes a bed of carefully graded media drained from underneath so that pretreated wastewater can be filtered, collected and distributed to final treatment and disposal systems. Sand is a commonly used media although anthracite, mineral tailings, glass and bottom ash have been used as a substitute. Sand filters remove contaminants through physical, chemical, and biological treatment processes.

Sand filter systems have been used as a component in wastewater treatment in the United States since the late 1800's.

Single Pass (Intermittent) Sand Filters vs. Recirculating Sand Filters. A single-pass sand filter system filters wastewater effluent through sand or other appropriate media producing a high quality effluent that can be used for irrigation or surface discharge after disinfection. A Recirculating Sand Filter, a modified version of the single-pass sand filter, recirculates wastewater effluent back through the filter for repeat filtering which helps improve performance and alleviate odor problems associated with open sand filters. Recirculating sand filters generally outperform single-pass filters in removal of BOD, TSS, and nitrogen.

Open vs. Buried Sand Filters. Sand filters can be “Buried” or “Open”. Buried sand filters consist of buried distribution piping which distributes the wastewater effluent above the sand/media filter. Open sand filters consist of a filter bed which is dosed with wastewater effluent from the surface via spray nozzles or distribution pipes. Typically, dosing via siphons or pumps are used for both buried and open filters. In general, open sand filters are preferred over buried filters when wastewater flow rates exceed 30,000 gpd. This is mostly due to economics—open filters can be hydraulically loaded more heavily than buried filters can.

Disinfection. The potential health risks associated with the discharge of treated wastewater have led to the wide use of disinfection as part of the treatment process in most centralized treatment systems. The disinfection process has become one of the primary mechanisms for the destruction or inactivation of pathogenic organisms in wastewater. All treatment processes remove some pathogens, but removal rates can be limited. The following outlines three methods of disinfection commonly used today. Each disinfection method has its advantages and disadvantages, and depending on the treatment needs, one method may be chosen over another.

Chlorination. Chlorine acts as a powerful oxidizing agent which has been employed effectively as a disinfectant in wastewater for over a century. Chlorine can be added to water as a gas (Cl_2) or as a liquid (sodium hypochlorite) or solid (calcium hypochlorite). The gas application tends to be a potential safety and/or handling hazard. Currently, the

liquid application is more commonly used in wastewater treatment, and the solid application is typically used only on very small systems.

Dechlorination. After chlorination, chlorine residual can remain in the effluent for hours. High chlorine residual, if discharged directly to surface waters, can have adverse impacts on the ecosystem of the surface waters. In order to minimize the effects of chlorine on a water body, dechlorination may be required prior to discharge. Sulfur dioxide, sodium bisulfite, and sodium metabisulfite are common chemicals used to reduce free and combined chlorine residuals prior to discharge to surface waters.

Ultraviolet Disinfection. Ultraviolet radiation, or “UV”, is germicidal in the wavelength range of 250 to 270 nm. This wavelength range is able to penetrate the cell wall of organisms in wastewater effluent and either kill the cell or prevent further replication. UV radiation is applied to the wastewater effluent by a low or medium pressure mercury arc lamp with high or low intensities. UV dosage rates are directly related to the amount of wastewater and the concentration of constituents to be removed. Ultraviolet disinfection is a successful form of disinfection when applied to non turbid wastewater effluent and at the correct dosage.

Ozone Disinfection. Ozone is an unstable gas which is produced when oxygen molecules are dissociated into oxygen atoms by an energy source, usually a high voltage alternating current (6 to 20 kilovolts). These atoms collide with other oxygen molecules to form Ozone. Ozone is generally produced on-site because it is unstable and decomposes to oxygen in a short time. The Ozone is applied to the wastewater effluent and, as it decomposes, it forms the hydrogen peroxy and hydroxyl ions, both of which are powerful oxidizing agents which cause cell wall destruction. This process is not widely used.

High-rate biological processes typically remove 85 % - 95% of the BOD₅ and Suspended Solids originally present in wastewater. The Activated Sludge process typically produces an effluent of slightly higher quality than trickling filters or rotating biological contactors. When a disinfection step is included, these processes can provide even higher (but not complete) removal of bacteria and viruses. These processes alone provide very little phosphorus, non-biodegradable organics, or dissolved minerals removal.

Tertiary Treatment

Tertiary treatment consists of nutrient removal or filtration for additional BOD₅ & Suspended Solids removal and can be provided in order to increase wastewater effluent quality before it is discharged to the receiving waters. Tertiary treatment is the final stage of treatment unless disinfection or post aeration is applied to the treatment train in which case it will come before those processes.

Nutrient Removal. Wastewater can contain high levels of nitrogen and phosphorus as described in Chapter 3. Nutrient removal typically consists of the removal of nitrogen and

phosphorus which can adversely impact the ecosystem of the receiving waters by causing eutrophication. Removal of nitrogen and/or phosphorus from wastewater effluent can be achieved either biologically or by chemical precipitation. Nutrient removal in a wastewater treatment plant is often more critical than in a decentralized system mainly due to the fact that larger volumes of wastewater are involved and due to the fact that effluent is usually discharged directly to surface waters rather than being discharged to the soil.

Nitrogen Removal. Nitrogen is present in wastewater mostly in the form of ammonia and organic nitrogen. Nitrogen removal is accomplished by the biological reduction of nitrogen from ammonia to nitrate (nitrification) and then from nitrate to nitrogen gas (denitrification). The nitrogen gas is then released to the atmosphere. Nitrification/denitrification processes require controlled conditions to encourage the appropriate biological communities to form. Recirculating sand filters, and nitrification/denitrification processes are the most common facilities used to accomplish nitrogen removal.

Phosphorus Removal. Phosphorus can be effectively removed by biological and chemical processes. Enhanced biological phosphorus removal is when a specific type of bacteria called polyphosphate-accumulating organisms are used to absorb large quantities of phosphorus within their cells. The biomass enriched with these bacteria is usually mixed with other biosolids and disposed of accordingly. Ferric chloride and aluminum sulfate are compounds which can be used to remove phosphorus by chemical precipitation. Chemical phosphorus removal tends to be more expensive although the space typically needed for chemical treatment in a facility is smaller than that needed for biological treatment and provides for less complex operation methods. Treatment plants which are required to discharge low concentrations of total phosphorus commonly have a sand filter as a final treatment stage, in order to remove most of the suspended solids which may contain phosphorus.

Filtration. Where required for polishing effluent suspended solids and/or for reduction of Giardia and enteric virus, sand filtration and/or microfiltration may also be required.

Package Plants

Conventional treatment plants are usually constructed of concrete tanks with pre-fabricated steel or fiberglass equipment inserts. Only pumps, instrumentation, disinfection equipment, controls, and other sensitive equipment usually need to be sheltered from the elements. A small laboratory/ office is usually required with such plants to properly monitor plant operation and to report daily influent and effluent parameters required by the NYSDEC discharge permit. Due to concrete installation costs and typically high operation and maintenance costs, a conventional plant may not be a cost effective solution for a small treatment system.

The so-called "packaged plant" designs, however, may be cost effective for small systems. They incorporate the various technologies used for conventional plants but are constructed of factory assembled, steel-walled tanks that together form a train of treatment components. Such systems have been economically used in subdivisions, mobile home parks, and small

communities. However, operation and maintenance costs are similar to those for conventionally constructed conventional treatment. An example of a package plant is a Sequential Batch Reactor (SBR) which typically combines the biological treatment and settling processes in one tank. Activated sludge is typically mixed with incoming wastewater, aerated, and allowed to settle, producing a high quality effluent. A portion of the settled biomass is re-aerated and returned to the head of the secondary treatment process. SBR's are becoming more common throughout the United States. This type of facility requires precise control of the mixing, aeration, and settling sequences, and therefore, requires computer controls; these are more suited for facilities that are well maintained and have a reliable power source.

Biosolids (Sludge) Treatment

Biosolids (sludge) separated during the various wastewater treatment process must be effectively dewatered, treated, and disposed of in an acceptable manner. The four most common treatment options for biosolids are aerobic digestion, anaerobic digestion, composting, and chemical stabilization. The goal of these treatment methods is to reduce the amount of pathogens in the biosolids, a goal also known as stabilization.

Aerobic Digestion. Aerobic digestion is the process by which aerobic organisms rapidly feed on organic materials in biosolids in the presence of oxygen. Bacteria rapidly consume organic material under aerobic conditions and convert it to carbon dioxide. Bacteria will die as the organic material is depleted and become food for other bacteria in a process known as endogenous respiration. This process results in solids reduction. Aerobic digestion processes occur much faster than anaerobic digestion. As a result, the capital cost is typically less. However, operation costs tend to be higher due to the energy costs associated with providing oxygen to the process through aeration.

Anaerobic Digestion. Anaerobic digestion is the process by which organisms degrade organic material without the presence of oxygen. Anaerobic treatment is much slower than aerobic treatment. Thermophilic digestion is a process in which sludge is fermented in heated tanks. Mesophilic digestion involves the natural digestion of the sludge during long periods of storage. In large treatment plants, enough methane gas may be produced during thermophilic digestion so that it can be utilized to create sufficient energy to help run engines and/or microturbines for on-site processes. Methane generation is sometimes seen as an advantage when used to power facilities. Disadvantages include high capital costs and a long processing time (up to 30 days). But the standards now require equally long processing for Aerobic Digestion in order to meet landspreading criteria.

Composting. Composting is an aerobic process that involves mixing the dewatered biosolids with wood chips, sawdust, or straw, which are sources of carbon. Bacteria digest both the wastewater solids and the added carbon source in the presence of oxygen which produces a large amount of heat. The resulting compost can be safely reintroduced to land or used for agriculture as a fertilizer as long as levels of toxic constituents are sufficiently low.

Chemical Stabilization. Lime may be mixed with sludge at a dosage sufficient to reduce pathogens in biosolids.

Alternative Methods of Wastewater Collection, Effluent Disposal, and Water Saving Technologies

The size and terrain of the service area help determine the most viable type of wastewater collection system that can be used. This chapter presents a number of commonly used wastewater collection systems and types of effluent disposal.

Alternative Methods of Wastewater Collection

Decentralized cluster and centralized wastewater treatment systems treat wastewater from multiple homes and businesses in a community. These systems rely on a central collection system in order to collect and convey wastewater to the community's treatment facility. Depending on terrain and configuration of the service area, there are a number of collection and conveyance methods that can be used in order to successfully transport wastewater from the service area to the treatment facility. Often multiple methods are employed in a system.

Conventional Collection Systems. Conventional collection systems are typically constructed of gravity flow sewer pipe of 8" or more in diameter. PVC pipe is typically used under normal service conditions; while ductile iron pipe is used where additional pipe strength is required – or certain safe separation requirements demand. Conventional sewers must be installed at slopes sufficient to maintain flow velocities to transport solids to prevent plugging. For maintenance purposes, these sewers must be installed in consistent horizontal and vertical alignment between manholes typically no farther than 400 feet apart. The constant slope requirement increases installation costs by requiring installation accuracy and by requiring the sewers to be deeper in areas where the ground surface rises between manholes.

Small Diameter Gravity Sewers from Septic Tanks. Small diameter gravity sewer systems consist of septic tanks for each service connection and small diameter (4-6") PVC effluent collection sewers. Smaller pipes can be used because the septic tanks trap solids and greases which tend to clog sewers, leaving only septic tank wastewater effluent to be transported in the pipes. Cleanouts are typically used instead of manholes for maintenance purposes and cost reduction.

Effluent Pump Station. Conventional collection systems are designed for gravity flow wherever possible. However, in some flat or hilly terrain, due to minimum sewer grade requirements or excessive sewer depth, pumping or lift stations may be necessary or economical. These are used in conjunction with septic tanks. Where services are too low for connecting to a mainline sewer by gravity, small effluent pump stations may be required. These can either be for single or multiple services.

Grinder Pump Stations. Grinder pumps can be used where connection to the collection system is not feasible by gravity. However, since grinder pumps only grind up solids and do not remove them from the sewage, as does a septic tank, such systems are typically only used when connected to conventional sewers or a complete system of pressure sewers. They are not recommended for use in decentralized systems because the removal rates in the primary treatment device (i.e. septic tank) can be hindered due to the grinding of solids and the reduction of settling rates.

Vacuum Sewers. Like grinder pump pressure sewers, vacuum sewers can be used for an entire collection system or just for lower elevation service areas. Vacuum sewers consist of one or more central vacuum sources and 4" or greater vacuum lines which are capable of handling all solids in normal wastewater. "Wet well" wastewater collectors are located such that they typically serve from 1 to 4 homes. When the waste in the wet well reaches a certain level, a valve in the wet well is actuated and the wastewater in the wet well is ejected to the central vacuum station. Wastewater from the central vacuum station either flows by gravity or is pumped to the treatment location.

Alternative Methods of Effluent Disposal

So far this manual has discussed surface and subsurface disposal. Surface disposal requires that the treated wastewater effluent being discharged from a Centralized Wastewater Treatment Facility meet certain removal rates and discharge requirements so as not to adversely impact the downstream surface waters to which it is discharged. Subsurface disposal systems as described in Chapter 6 are all designed to provide an acceptable level of treatment in the soil prior to the wastewater effluent returning to the ground water.

Alternative disposal methods could be considered on a site by site basis as a practical solution for disposal in place of the more conventional disposal methods. The following methods of disposal typically require that the wastewater effluent be highly polished prior to being discharged in this manner due to the smaller amount of treatment that these methods provide.

Irrigation Systems. Irrigation systems are similar to absorption fields in that they use the land's natural assimilative capacity to absorb treated and polished wastewater effluent. Irrigation systems are designed to allow the water and nutrients to be used by vegetation (typically crops such as orchards, vineyards, and some processed food crops or crops that are not consumed by humans. Plants extract water and nutrients such as nitrogen from the effluent by absorption through the roots which allows for healthy vegetative growth and results in the reduction of water that percolates through the soil, reducing the possibility of over saturation of

the soils. Plant roots introduce oxygen, which allows aerobic microorganisms at the top of the soil profile to digest some of the organic matter in the effluent and provide further treatment. Spray and drip irrigation are the two most common methods in use.

Drip Irrigation. Drip irrigation systems distribute wastewater effluent just below the surface of the ground. Pressurized perforated tubing is installed just below the ground surface typically in a closed loop configuration. Polished wastewater effluent is slowly and evenly distributed within the root zone of the soil profile. Because wastewater effluent is discharged below the ground surface, drip irrigation systems do not provide for as much evapotranspiration to occur as with spray irrigation systems. Effluent is not directly exposed to the air, and there is no risk of wind-transported pathogens as there is with spray systems. Therefore, aerobic treatment and disinfection are not always necessary prior to drip irrigation. Drip irrigation also tends to produce fewer odors.

Spray Irrigation. Spray irrigation systems use sprinkler systems to distribute the wastewater effluent over the surface of the ground. Spray irrigation distributes effluent more evenly over the ground surface which allows for a greater amount of evaporation to occur. Spray irrigation takes advantage of the entire assimilative capacity of the soil profile, because absorption and infiltration start at the surface rather than subsurface. There is potential for pathogens to be carried by the wind, causing possible health hazards. Before spray irrigation, wastewater is typically well treated by either an aerobic treatment unit or a septic tank-sand filter combination and then disinfected through a chlorination process before it is used for irrigation. Irrigation fields should be fenced in to ensure that people and animals do not enter the area.

Water Saving Technologies

Composting Toilets. Sometimes called biological toilets, dry toilets or waterless toilets, composting toilets collect and control the composting of excrement, toilet paper, carbon additive, and sometimes food wastes. A composting toilet differs from a septic tank because a composting toilet system relies on unsaturated conditions where aerobic bacteria break down wastes similar to yard waste composters. Properly sized and operated, a composting toilet can break down waste by 10% to 30% of its original volume. The resulting end-product is a stable soil-like material called "humus," which is typically removed and disposed of by a licensed septage hauler or buried in accordance with state and local regulations.

Incinerator Toilets. These are self-contained units which have a commode-type seat connected to a holding tank which has a gas-fired or electric incinerating device. The resulting end-product is primarily small amounts of a stable ash product and water which can be disposed of in a landfill.

The first known water closet with flushing device was installed in the Knossos Palace in Crete in 1700 BC by King Minos.

Chemical Toilets. Toilets such as port-a-potties have chemicals that act as a disinfectant as well as a bacterial inhibitor. The chemicals help keep odor and bacterial growth to a minimum

while the capacity of the tank is being utilized. A licensed septage hauler removes and disposes of the waste in accordance with state and local regulations.

Recirculating Toilets. Toilets that do not require water to operate. A non-aqueous medium such as mineral oil is used to carry away waste. Water-based urine and solid wastes are separated from the medium which is then filtered and reused. The separated waste is then stored for removal and disposed by a licensed septage hauler in accordance with state and local regulations.

Five Recommended Treatment Systems

A community chooses its wastewater management structure, collection and treatment system as a result of a decision-making process involving its professional engineering firm, its political leaders, its stakeholders and its constituency. This process is described more fully in the companion volume, *The Guide to Developing a Municipal Wastewater Project for Small Rural Communities in New York State*. A text book discussion of alternatives cannot replace such a process because valid decisions and recommendations for a wastewater management structure and for a wastewater collection and treatment system cannot be made without extensive community-specific and site-specific studies that must be carried out by a qualified professional engineer working directly for a community in a decision-making process involving real community input.

However, there are some systems that deserve to be considered in the process of such studies.

1. Septic Maintenance District (SMD) with on-site systems.

On-site septic tank and subsurface treatment and disposal systems, if properly applied to adequate site(s), and if properly operated and maintained, are effective. These systems are the least costly wastewater management option in initial capital costs, on-going operation and maintenance costs, and future replacement or rehabilitation costs.

The first element of a successful SMD is whether the individual lots are adequate in size, and hydrogeologic and physical characteristics. The sites must be evaluated with caution. If a large majority of the community sites can support an adequate, properly sized and designed system meeting current regulatory requirements including the applicable (100% or 50%) reserve requirement, and if the balance of the community's sites can support specially engineered systems with reserves or contingency plans, then the community can pursue the development of this option with reasonable confidence. If a significant number of sites are insufficient, then the septic maintenance district option should be rejected in favor of an option with more real potential for full and long-term success. Said another way, a community should not accept a significant risk of failure in the interest of cost. In this regard, it should be noted that failed solutions are usually eventually far more expensive than more costly but successful solutions.

Another key to a successful SMD is the creation of a management structure that supports a pro-active operation and maintenance effort including frequent septic tank pump-outs, frequent periodic scheduled system inspections, and prompt rehabilitation or replacement of failing systems or components. The septic maintenance district provides the legal management structure. The community must be willing to provide the leadership and financial support for the operation of the system.

If the circumstances are near optimal, a septic maintenance district operating a group of on-site septic systems, single or clustered, is the most economical alternative, and therefore should be considered first among all options.

2. Community System

If in a specific community, a septic maintenance district represents too much risk for failure because a significant number of individual sites are inadequate for on-site septic systems, the next option that should be considered is the community system. If an adequate site(s) can be found for a septic tank/absorption field system for the entire community or a few large sections of the community, this option can be effective and is the least expensive of all others except the septic maintenance district option. Poor soils, proximity to streams, flooding, and steep slopes must be avoided.

Again, the sites must be evaluated cautiously before concluding that they are fully adequate. And again, the community must be willing to establish and support the proper management structure and the pro-active operation and maintenance effort.

3. Enhanced Community System

A community septic system can be enhanced just as a single on-site septic system can. This would be especially appropriate where land is expensive or where available adequate sites are somewhat small and where regulatory agencies are willing to increase application rates allowing for a reduced-sized absorption field(s) in return for construction of the treatment enhancement.

Such enhancement options include but are not limited to:

- a. recirculating sand filter enhancement with reduced absorption field(s) sizes
- b. aeration, biofilter, nutrient removal
- c. recirculating sand filters, disinfection and surface discharge
- d. package trickling filter and absorption fields
- e. constructed wetlands/aquatic plant systems and absorption fields

Again, on an adequate site, these options will generally be cheaper to build, maintain and operate than conventional wastewater treatment and surface discharge.

4. Conventional Wastewater Treatment and Surface Discharge

In spite of the advantages of the SMD, the community system and the enhanced community system, many communities simply do not have the required site characteristics available on properties in or near the community. In those cases, the community will have to look at the option of conventional wastewater treatment and surface discharge or effectively abandon the value of its real estate, its future and its environment. A conventional wastewater treatment and surface discharge system is more costly, especially in operation and maintenance costs, but it can be done.

There are a couple of advantages. First, it is a very well developed technology and therefore is almost certain to be effective. Second, the siting requirements are much less stringent since wastewater treatment plants can be constructed on poor soils and within flood plains.

Of the currently available technologies, one that deserves consideration is the Sequencing Batch Reactor (SBR), a form of the extended aeration version of the mixed liquor suspended solids or activated sludge system. The advantage of the SBR is that by treating wastewater in batches, the SBR system allows for both biological treatment and final settling in the same tanks resulting in a lower treatment plant footprint and capital cost while at the same time providing the most effective secondary treatment biological systems available.

Another option deserving of consideration is the recirculating sand filter.

5. Pumping to an Existing Wastewater Treatment System

Some communities are located relatively near a neighboring community's existing wastewater collection and treatment system. If that neighbor is willing to sell some of its excess capacity at a reasonable price and if that neighbor is willing to take on the responsibility for treating the wastewater for a reasonable cost or for other considerations, such as annexation in the case of a town hamlet and a village, then pumping wastewater to the existing system could prove to be the best option. When a community proposes such a deal to its neighbor, it must remember that the neighbor has no legal or moral obligation to provide the service requested and that therefore the proposal must be financially advantageous to the neighbor. Indeed, if the deal were not in the interest of the neighbor, then the neighbor would have an obligation to its citizens to reject the idea.

One disadvantage to the option of pumping to a neighboring community's wastewater system is that the availability of future additional wastewater treatment capacity is entirely within the power of the neighbor to grant or deny.

Maintenance and Public Education

It is important for homeowners to understand their on-site wastewater treatment system and to have the knowledge to maintain and protect it. In addition, if they are served by a centralized system it is also important for them to practice water saving techniques and be aware of what is being disposed of down the drain. There are many simple day-to-day practices that can help maintain and protect on-site wastewater treatment systems and help keep the community centralized treatment system functioning properly and therefore help protect and maintain the health of the community. Typically local sewer ordinances prohibit practices that can interfere with wastewater conveyance, treatment and disposal.

On-site wastewater system maintenance

- Don't dispose of household wastes such as paper, food products, and sanitary napkins down drains or toilets. Garbage disposals can clog pipes and absorption fields.
- Keep the amount of household cleaners and toxic substances that go down the drain to a minimum.
- Spread out your water usage throughout the day in order to avoid surges of high water flows to the septic system.
- Do not drive or park vehicles on any part of your septic system. This can cause damage to pipes, structures, and impact the performance of the absorption field.
- Landscape your absorption field with grass and keep trees and brush away so that the root systems don't damage the system.
- Use water efficiently and employ daily water saving techniques.
- Make sure to inspect your system regularly and perform necessary pump outs.
- Contact your local health department for additional information regarding your on-site water and wastewater utilities.

Water Saving Practices for the Home

- When washing dishes by hand, don't let the water run while rinsing. Fill one sink with wash water and the other with rinse water.
- When you shop for a new appliance, consider those offering cycle and load size adjustments and carry the energy star label. They are more water and energy-efficient than older appliances.
- Run your washing machine and dishwasher only when they are full.
- Keep a pitcher of water in the refrigerator instead of running the tap for cold drinks.
- If your shower can fill a one-gallon bucket in less than 20 seconds, replace it with a water-efficient showerhead (i.e. 2.0 gpm nozzle).
- Time your shower to keep it under 5 minutes.
- If the toilet flush handle frequently sticks in the flush position, letting water run constantly, replace or adjust it.
- If your toilet was installed prior to 1980, place a toilet dam or bottle filled with water in your toilet tank to cut down on the amount of water used for each flush. Be sure these devices do not interfere with operating parts, or install low-volume toilets. Newer toilets use less gallons per flush. (Approximately 1.5 gallons per flush.)
- Make sure your toilet flapper doesn't stick open after flushing.
- Put food coloring in your toilet tank. If it seeps into the toilet bowl, you have a leak.
- Designate one glass for your drinking water each day. This will cut down on the number of times you run your dishwasher.
- Grab a wrench and fix leaky faucets. It's simple, inexpensive, and saves water.
- Turn the faucets off tightly after each use.
- Turn off the water while you brush your teeth
- Insulate hot water pipes so you don't have to run as much water to get hot water to the faucet.

If every household in America had a faucet that dripped once each second, 928 million gallons of water a day would leak away.

- Install water softening systems only when necessary. Save water and salt by running the minimum number of regenerations necessary to maintain water softness, or consider demand-type softeners that are volume-regulated vs. timer-regulated.
- Cook food in as little water as possible. This will also retain more of the nutrients.
- Select the proper size pans for cooking. Large pans require more cooking water than may be necessary.
- Turn off the water while you shave
- Consider reusing your towels prior to laundering.
- When you are washing your hands, don't let the water run while you lather.
- Never put water down the drain when there may be another use for it such as watering a plant or garden, or cleaning.
- Verify that your home is leak-free, because many homes have hidden water leaks. If your home is metered, read your water meter before and after a two-hour period when no water is being used. If the meter does not read exactly the same, there is a leak. Repair dripping faucets by replacing washers. If your faucet is dripping at the rate of one drop per second, you can expect to waste 2,700 gallons per year which can strain your septic system.
- Avoid flushing the toilet unnecessarily. Dispose of tissues and other such waste in the trash rather than the toilet.
- Retrofit all wasteful household faucets by installing aerators with flow restrictors.
- Do not use running water to thaw meat or other frozen foods. Defrost food overnight in the refrigerator or by using the defrost setting on your microwave.
- Consider installing an instant water heater on your kitchen sink so you don't have to let the water run while it heats up. This can reduce heating costs for your household.
- When adjusting water temperatures, instead of turning water flow up, try turning it down. If the water is too hot or cold, turn the offender down rather than increasing water flow to balance the temperatures.
- Do one thing each day that will save water. Even if savings are small, every drop counts.
- Encourage your friends and neighbors to be part of a water-conscious community.

The average five-minute shower takes between 15 to 25 gallons of water.

An automatic dishwasher uses approximately 9 to 12 gallons of water while hand washing dishes can use up to 20 gallons.

DEFINITIONS

Definitions

Absorption	The process by which one substance is taken into and included within another substance, such as the absorption of water by soil or nutrients by plants. (USEPA)
Absorption area or field	The area of original soil that is designed to accept effluent.
Aeration	Introducing oxygen (via air) to wastewater in the septic tank in order to provide an oxygen rich environment for aerobic organisms.
Aerobic	Having molecular oxygen as a part of the environment, or growing or occurring only in the presence of molecular oxygen, (as in "aerobic organisms"). (USEPA)
Aerobic treatment	The digestion of organic matter and settleable solids in an oxygenated environment to produce a clarified liquid.
Anaerobic	Characterized by the absence of molecular oxygen, or growing in the absence of molecular oxygen (as in "anaerobic organisms"). (USEPA)
Biochemical Oxygen Demand (BOD)	A commonly used gross measurement of the concentration of biodegradable organic impurities in wastewater. The amount of oxygen, expressed in milligrams per liter (mg/L), required by bacteria while stabilizing, digesting, or treating organic matter under aerobic conditions is determined by the availability of material in the wastewater to be used as biological food and the amount of oxygen used by the microorganisms during oxidation. BOD ₅ is the amount of oxygen consumed by the microorganisms in the wastewater during a five-day period. (USEPA)
Biomat	The layer of biological growth and inorganic residue that develops at the wastewater soil interface and extends up to about 1 inch into the soil matrix. The biomat controls the rate at which pretreated wastewater moves through the infiltrative surface/zone for coarse- to medium-textured soils. This growth may not control fluxes through fine clay soils, which are more restrictive to wastewater flows than the biomat. (USEPA)
Centralized system	A managed system consisting of collection sewers and a single treatment plant used to collect and treat wastewater from an entire service area.
Cluster system	A wastewater collection and treatment system under some form of common ownership that collects wastewater from two or more dwellings or buildings and conveys it to a treatment and dispersal system located on a suitable site near the dwellings or buildings.
Combined system	A management system consisting of a combination of decentralized and centralized systems in a community.
Decentralized system	An onsite or clustered system used to collect, treat, and disperse or reclaim wastewater from a small community or service area.
Denitrification	The biochemical reduction of nitrate or nitrite to gaseous molecular nitrogen or an oxide of nitrogen. (USEPA)
Effluent	Sewage, water, or other liquid, partially or completely treated or in its natural state, flowing out of a septic tank, subsurface wastewater infiltration system, aerobic treatment unit, or other treatment system or system component. (USEPA)
Eutrophic	A term applied to water that has a concentration of nutrients optimal, or nearly so, for plant or animal growth. In general, nitrogen and phosphorus compounds contribute to eutrophic conditions in coastal and inland fresh waters, respectively. (USEPA)

Eutrophication	The increased growth of plants and algae that accompanies eutrophication depletes the dissolved oxygen content of the water and often causes a die-off of other organisms.
Evapotranspiration	The combined loss of water from a given area and during a specified period of time by evaporation from the soil or water surface and by transpiration from plants. (EPA)
Nitrification	The biochemical oxidation of ammonium to nitrate. (USEPA)
Onsite Wastewater Treatment System (OWTS)	A system relying on natural processes and/or mechanical components that is used to collect, treat, and disperse/discharge wastewater from single dwellings or buildings, also known as a septic system. (USEPA)
Pathogens	Microorganisms that cause infectious diseases.
Percolation	The flow or trickling of a liquid downward through a contact or filtering medium. (USEPA)
Permeability	The ability of a porous medium such as soil to transmit fluids or gases. (USEPA)
Pretreatment system	Any technology or combination of technologies that precedes discharge to a subsurface wastewater infiltration system or other final treatment unit or process before final dissemination into the receiving environment. (USEPA)
Septic tank	A buried, preferably watertight tank designed and constructed to receive and partially treat raw wastewater. The tank separates and retains settleable and floatable solids suspended in the raw wastewater. Settleable solids settle to the bottom to form a sludge layer. Grease and other light materials float to the top to form a scum layer. The removed solids are stored in the tank, where they undergo liquefaction in which organic solids are partially broken down into dissolved fatty acids and gases. Gases generated during liquefaction of the solids are normally vented through the building's plumbing stack vent. (USEPA)
Soil structure	The combination or arrangement of individual soil particles into definable aggregates, or peds, which are characterized and classified on the basis of size, shape, and degree of distinctness. (USEPA)
Soil texture	The relative proportions of the various soil separates (e.g., silt, clay, sand) in a soil. (USEPA)
Suspended solids	Organic and inorganic matter suspended in wastewater.
Total Suspended Solids (TSS)	Measure of suspended solids in mg/liter of water.
Wastewater	Water that has been used, as for washing, flushing, or in a manufacturing process, and so contains waste products; sewage.

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