Onsite Sewage Treatment and Disposal Systems: An Overview[1]

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*This publication is part of a series titled **Onsite Sewage Treatment and Disposal Systems**, commonly referred to as septic systems. This series is intended to give state and local government officials, soil scientists, consulting engineers, Extension agents, and citizens a basic understanding of onsite wastewater treatment and the behavior of different wastewater-borne contaminants coming from septic systems.*

Introduction and Purpose

Domestic wastewater (sewage) contains a mixture of contaminants, including nitrogen, phosphorus, and disease-causing organisms called pathogens. It may also contain organic compounds of concern, such as pharmaceuticals or household chemicals. Before domestic wastewater is discharged to the environment, it must be treated to remove contaminants. This treatment (1) can occur centrally at one municipal sewage treatment plant that receives wastewater from a community, (2) may be distributed in space with several smaller treatment plants called a decentralized treatment system, or (3) may occur with onsite sewage treatment and disposal systems (hereafter referred to as septic systems) that treat wastewater from an individual home or business and dispose of it at that location.

Nearly one in four households in the United States and about one in three households in Florida depend on septic systems. In Florida, it is estimated that over 2.5 million septic systems are in use, discharging approximately 426 million gallons per day (Meeroff et al. 2008). The Florida Department of Health regulates septic systems and issues construction permits. A recent review of permitting records for Florida from 1990 to 2006 indicated that 95% of septic systems are residential systems. See Table 1 for detailed information on the number of septic systems serving other sources in Florida (Lowe et al. 2007).

These systems most commonly consist of a septic tank and a drain field (Figure 1). A drain field is also referred to as a leach field, soil infiltration or absorption system, or soil treatment unit (US EPA 2011). Relatively simple in design, septic systems can be a cost-effective and reliable means of removing contaminants from household wastewater before discharging it into the environment. Public health and environmental protection depend on the degree to which a septic system can remove harmful biological and chemical contaminants from household wastewater. More advanced technologies have gained popularity in recent years as concerns have grown about protecting sensitive environments. The Florida Department of Health maintains design criteria for septic systems to ensure public health and environmental protection and to make sure that onsite systems are sited within properly functioning soils. These criteria include requirements for the size and placement of drain fields, which depend on soil type and expected waste volume (FDOH 2011).

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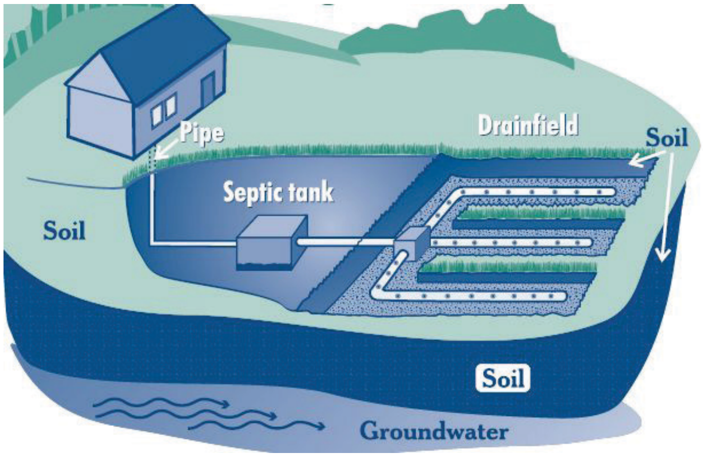

Figure 1. A conventional gravity onsite sewage treatment and disposal system or septic system.
Credits: US EPA (2011)

This publication introduces common types of septic systems and briefly discusses onsite wastewater flow and the contaminants found in wastewater. Subsequent publications in this series take a closer look at the behavior and transport of contaminants like nitrogen, phosphorus, bacteria, protozoa, viruses, and organic chemicals in wastewater treated by septic systems.

Functions and Types of Septic Systems

The basic functions of a septic system include the following:

- Receive wastewater (sewage) from the property, generally the building sewer.
- Separate solid waste materials from the wastewater in one or several tanks.
- Provide additional treatment and digestion of waste in one or several tanks.
- Dispose of the treated water. In Florida, disposal is through a drain field in nearly all cases. The drain field serves both as a means to receive and discharge the water and as a treatment unit.

Several septic system designs exist to carry out the above functions. A few of these technologies are described below.

Conventional Septic Systems

Most septic systems in the United States are conventional gravity flow septic systems, which means that instead of a motorized pump, these rely on gravity to move household wastes through the treatment system. The components of a gravity flow system are a septic tank and a drain field. Occasionally, the septic tank may be lower than the drain field, and a pump must be additionally installed to lift the wastewater into the drain field for disposal.

The septic tank consists of a buried watertight tank that receives wastewater from the home plumbing system (Figure 1). It works as follows:

- Wastewater enters the tank from the property's sewage pipes.
- Solid wastes settle to the bottom because of gravity and form what is called sewage *sludge*.
- Fats, oils, and grease float to the top and form what is called *scum*.
- Anaerobic bacteria in the septic tank carry out the first stage of treatment by breaking down degradable wastes in the scum, water, and sludge. This results in a reduction of sludge volume by 40%, biochemical oxygen demand by 60%, and suspended solids by 70% (Reneau et al. 1989). Gases resulting from this process escape through the plumbing vents, the drain field, or the top of the tank, and liquids become part of the remaining wastewater.
- The settled, anaerobically pretreated wastewater (called septic tank *effluent*) then flows out of the tank and moves by gravity into a drain field.
- In the drain field, the effluent enters the soil or similar material.
- Once in the soil, the water leaches, percolates, or moves downward through the soil and eventually becomes groundwater. Along the way, filtering and further removal of contaminants can occur.
- Periodic pumping of the septic system is necessary to remove built up *scum* and residual *sludge*.

If the septic system is working properly, the effluent that flows out of the septic tank is clarified, or contains few solids. However, it will still have an odor and carry contaminants. For further contaminant removal, the septic tank effluent must percolate through suitable unsaturated soil. This is accomplished with the soil treatment unit or drain field, which consists of a series of trenches, or perhaps a single bed, fitted with perforated pipes and chambers that receive wastewater from the septic tank and allow its seepage into the underlying soil. The importance of the unsaturated soil in providing treatment is the reason for increasing requirements over the last decades that the drain field be installed in unsaturated soil above groundwater. Old drain fields were frequently installed closer to or in the groundwater. Figure 1 shows how the drain field is typically configured in relation to the septic tank.

The soil underneath the drain field is the most important treatment component through which the effluent passes before it reaches groundwater. Thus, soil properties are important for properly siting a septic system. The thickness of unsaturated soil (i.e., depth to water table), permeability, texture, and clay mineralogy affect the degree to which the soil renovates the septic tank effluent. There must also be a 24-inch separation between the infiltrative surface of the soil treatment unit (typically the bottom of the drain field) and the wet season water table (the highest level of the saturated zone in the soil in a year with normal rainfall). It is also the level to which the water table can be expected to rise in a normal wet season.

Low-Pressure Dosing Systems

One disadvantage of conventional gravity flow septic systems is that gravity flow limits how high and far effluent can move. The resulting uneven distribution of the effluent in the drain field can cause localized overloading of the soil in the drain field. This overloading can hamper treatment or cause clogging in drain field pipes. Furthermore, some areas have slowly permeable soils that may not be able to handle large volumes of effluent all at once. To overcome these problems, a low-pressure dosing system may be used as an alternative to the conventional gravity flow system. In this system, wastewater is treated in a septic tank just as in the conventional septic system, but before distribution to the drain field, wastewater is stored in a pump tank. From there, effluent is pumped evenly to the drain field at regular intervals in a controlled manner. Low-pressure dosing systems overcome problems associated with peak flows from gravity systems and allow utilization of large drain field placement in soils that otherwise might not be suitable.

Aerobic Treatment Units

A different shortcoming of the conventional septic system is that the clarified septic tank effluent still contains biodegradable solids and liquids. These can lead to eventual clogging of a drain field installed in soil that otherwise could percolate the volume of wastewater. A useful alternative for these sites is the aerobic treatment unit (ATU). The ATU is a sewage treatment system that replaces the septic tank or is added after the septic tank of a conventional septic system. ATUs introduce air into the sewage and use an aerobic (high oxygen) process rather than the anaerobic process used in conventional septic systems (Figure 2). By aerating (adding oxygen from air) the waste, the treatment process rate is increased, and many contaminants will be reduced to levels considerably lower than from a conventional septic tank. Effluent from an ATU is discharged into a drain field for further treatment in the soil, just as with a conventional septic tank system. ATUs usually refer to systems containing an aerator, but trickling or media filter technologies can also be included. ATUs require a higher energy input to power the aerator or pumps and regular operation and maintenance to maintain performance.

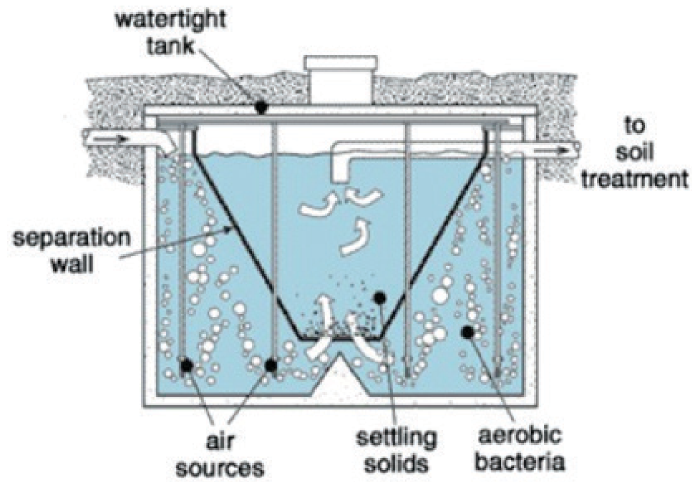

Figure 2. An aerobic treatment unit (ATU) for onsite sewage treatment.
Credits: FDOH (2011)

Advanced Onsite Treatment System Design

Treatment better than that performed by conventional septic systems is sometimes referred to as "advanced treatment." The previously mentioned ATUs are part of this group. Additionally, in Florida, technologies would generally fall into a category of performance-based treatment systems (PBTS), which are engineered systems designed to achieve specified levels of contaminant removal.

PBTSs for nitrogen reduction are designed so that anaerobic treatment follows aerobic treatment to encourage greater nitrogen reduction from the wastewater. This reduction in nitrogen is made possible because aerobic treatment encourages the conversion of nitrogen in the waste to nitrate, which is subsequently converted to nitrogen gas in the anaerobic phase of treatment. The nitrogen gas can easily escape to the atmosphere, where it no longer poses a threat to the soil/water environment. In recent years, many ATU manufacturers have begun to incorporate advanced nitrogen removal technology into their design, and research continues on the effectiveness of these new technologies. In Florida, the Onsite Sewage Nitrogen Reduction Strategies Project (http://www.doh.state.fl.us/environment/ostds/research/Nitrogen.html) funded by the Florida Department of Health has a goal to research and recommend technologies for greater nitrogen removal from septic systems.

A PBTS can also be fitted with a disinfection unit that reduces pathogen numbers in the effluent. Still another type of PBTS aims to clean up solids and biodegradable material in the wastewater with the goal of reducing drain field sizes in soils that can accommodate the wastewater. This reduction is feasible because wastes are ideally treated more completely by the PBTS than by a conventional septic tank or ATU.

Wastewater Flow in Septic Systems

The design and siting of septic systems are important management considerations for protecting public health and environmental quality. To effectively manage wastewater from septic systems, we need accurate knowledge about the flow rates and constituents present in the wastewater. In particular, a good estimation of expected flow rates that are rarely exceeded is necessary to properly determine the size of the septic tank and drain field. Factors that can affect wastewater flow rates are the number of occupants in a dwelling, type of dwelling unit, geographic location, and household water use practices. Thus, wastewater flow patterns vary in volume and quality because of variations in water use within single locations and across geographic areas. Mayer et al. (1999) summarized indoor residential water use for major metropolitan areas across the United States (Table 2). The mean daily per capita indoor water use (gallons per person per day) across 12 study areas was 69 (ranging from 54 to 83), with the median daily per capita indoor use at 60. However, expected flow volumes for individual households are more useful than per person water use statistics. Therefore, many states base septic system designs on a set number of wastewater gallons per day per bedroom by assuming 2 people per bedroom and a daily per capita flow rate of 50-60 gallons. A few states, including Florida, also require increased wastewater design flows depending on the square footage of the home, as described in Florida Administrative Code, Rule 64E-6 (FL Department of State 2011).

Wastewater Quality in Septic Systems

Sources of household wastewater include waste from garbage disposals, toilets, baths, sinks, dishwashers, and washing machines. Together they contribute numerous chemical and biological constituents to wastewater. Table 3 summarizes various types of wastewater contaminants and their main sources. Table 4 outlines nonpathogenic contaminant contributions by different sources (garbage disposal, toilet, sinks, and appliances). Consult Table 5 for a more detailed breakdown of contaminants, including pathogens, commonly found in household wastewater.

The shallow sandy soils that cover much of Florida can be especially limited in their ability to remove contaminants from wastewater effluent—making proper septic system design and siting all the more critical. In the Florida Keys, for example, septic systems were shown to contribute 39% nitrogen and 42% phosphorus to oceanic surface waters (US EPA 1996). In 1990, the Florida Department of Health began investigations in onsite technologies for reducing the environmental impacts from septic systems. Anderson et al. (1998) provide a comprehensive review of these technologies and report significant recent improvements in nutrient removal for new technologies. Subsequent papers in this series address specific environmental concerns associated with nutrients as well as pathogens and organic contaminants, and discuss how these contaminants behave in the soil drain field environment and how they can be mitigated.

Summary

More than one-third of Florida households rely on septic systems, which most commonly consist of a septic tank and a drain field. When properly designed and maintained, these systems can be a cost-effective and reliable means to protect public health and the environment from contaminants, including nitrogen, phosphorus, pathogens, and toxic organic chemicals. Nitrogen pollution from septic systems is of particular concern in Florida. Research is ongoing on new technologies to improve nitrogen removal from septic systems. This publication reviewed the functions of septic systems, design alternatives, and typical flow and quality characteristics of domestic wastewater. Subsequent publications in this series discuss the behavior of individual contaminants in septic systems.

Consult the following EDIS articles in this series for more information on these topics:

SS550/SL348—*Onsite Sewage Treatment and Disposal Systems: Nitrogen*

SS551/SL349—*Onsite Sewage Treatment and Disposal Systems: Phosphorus*

SS552/SL350—*Onsite Sewage Treatment and Disposal Systems: Bacteria and Protozoa*

SS553/SL351—*Onsite Sewage Treatment and Disposal Systems: Viruses*

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Table 1. Types of establishments served by septic systems in Florida from 1990 to 2006.

Source type	Number of systems	Percent of all systems
Residential	480,834	95.5
Office	4,291	0.8
Mobile home/RV	4,064	0.8
Warehouse	1,924	0.4
Church	1,348	0.3
Store/shop	1,260	0.2
Pool	1,011	0.2
Garage	878	0.2
Restaurant	756	0.2
Park	595	0.1
Unknown	524	0.1
Other*	5,979	1.2

*Includes school, barn, commercial, auto repair, cabin/camp, accessory, factory, food outlet, nursing home, hotel, vet/animal shelter, bar, doctor, country club, institution, salon, etc.
Source: Lowe et al. (2007).

Table 2. Daily per capita water use in residences in 12 cities in North America.

Study site	Sample size (number of homes)	Mean daily per capita use (gallons per person per day)
Seattle, WA	99	57.1
San Diego, CA	100	58.3
Boulder, CO	100	64.7
Lompoc, CA	100	65.8
Tampa, FL	99	65.8
Walnut Valley, CA	99	67.8
Denver, CO	99	69.3
Las Virgenes, CA	100	69.6
Waterloo and Cambridge, ON	95	70.6
Phoenix, AZ	100	77.6
Tempe and Scottsdale, AZ	99	81.4
Eugene, OR	98	83.5
Average of 12 study sites		**69.3**
Source: Mayer et al. (1999).		

Table 3. Common contaminants in domestic wastewater.

Wastewater constituent	Main sources	Description
Biochemical oxygen demand	Organic material from human and household waste	Refers to the amount of dissolved oxygen organisms need to degrade wastes in wastewater. When excluding oxygen demand from nitrogen compounds, referred to as $CBOD_5$ (Five-day Carbonaceous Biochemical Oxygen Demand).
Total suspended solids	Organic and inert materials from human and household waste	A portion of wastewater that has resisted settling and is retained when passed through a filter. Also indicates wastewater clarity. Can clog the soil absorption system.
Total nitrogen	Feces, urine	Three forms of nitrogen are commonly measured: ammonium (NH_4), nitrates (NO_3), and nitrites (NO_2). Total Nitrogen is the sum of total Kjeldahl nitrogen (organic and reduced nitrogen), ammonium, and nitrate-nitrite.
Total phosphorus	Feces, chemicals used	Occurs in wastewater bound to oxygen to form phosphates. Phosphates are classified as orthophosphates, polyphosphates, and organic phosphates.
Pathogens	Feces	Includes bacteria, viruses, and protozoa.
Fecal coliform	Feces	A specific enteric bacterial group used as an indicator organism for the presence of pathogens and used to determine if wastewater has been adequately treated.
Fats, oils, greases	Feces and food wastes	The combination of fats, oils, greases, and other related constituents in wastewater. Excessive amounts of these can clog systems, create odors, and increase biological oxygen demand.
Specific organic compounds	Excretion of drugs in feces; chemicals present in household products	Includes volatile organic compounds in household chemicals as well as compounds from pharmaceutical and personal care products, pesticides, and other miscellaneous organics.

Source: FDOH (2011).

Table 4. Domestic wastewater contaminant contributions by different sources.

Parameter	Garbage disposal	Toilet	Bath, sink, appliances	Total
	grams per person per day			
Biological oxygen demand	18.0	16.7	28.5	63.2
Total soluble solids	26.5	27	17.2	70.7
Total nitrogen	0.6	8.7	1.9	11.2
Total phosphorus	0.1	1.6	1.0	2.7
Source: US EPA (1992).				

Table 5. Average contaminant concentrations in untreated domestic wastewater.

Parameter	Average concentration
Biological oxygen demand	420 mg/L
Total soluble solid	232 mg/L
Total nitrogen	60 mg/L
Ammonia-nitrogen	14 mg/L
Nitrate-nitrogen	1.9 mg/L
Organic nitrogen	43 mg/L
Total phosphorus	10.4 mg/L
Fecal coliform	3×10^4/100 mL
Fecal streptrococci	3×10^4/100 mL
Total bacteria	1×10^8/100 mL
Enteric virus	35–7,000 PFU/L*

*PFU stands for plaque-forming unit. It is a measure of the number of infectious virus particles in a water sample.
Source: Lowe et al. (2009).