United States Environmental Protection Agency

EPA841-R-10-002
May 12, 2010

Guidance for Federal Land Management in the Chesapeake Bay Watershed

Chapter 6. Decentralized Wastewater Treatment Systems

Nonpoint Source Pollution
Office of Wetlands, Oceans, and Watersheds
U.S. Environmental Protection Agency

Chapter 6. Decentralized Wastewater Treatment Systems

Contents

1 Nitrogen-Reduction Implementation Measures

The U.S. Environmental Protection Agency (EPA) recommends protecting surface waters in the Chesapeake Bay watershed from nitrogen (N) discharged by decentralized wastewater treatment systems by using N-reduction technologies and enhanced system management.

Implementation Measures:

D-1. Specify the following risk-based, N-removal performance levels for all new and replacement individual and cluster systems:

- 20 milligrams per liter (mg/L) total nitrogen (TN) standard* for all new subdivisions and commercial and institutional developments and all system replacements throughout the Chesapeake Bay watershed.
- 10 mg/L TN standard* for all new developments and all system replacements in sensitive areas—i.e., between 200 and 1,000 feet of the ordinary high water mark of all surface waters, or between 200 and 500 feet of an open-channel MS4.
- 5 mg/L TN standard* for all new developments and system replacements in more sensitive areas—i.e., between 100 and 200 feet of the ordinary high water mark of all surface waters, or between 100 and 200 feet of an open-channel MS4.
- 100-foot setback from surface waters and open channel MS4s for all effluent dispersal system components.

> * Effluent standards can be met by either system design or performance, as verified by third-party design review or field verification. Except in sandy or loamy sand soils, a 5 mg/L N reduction credit is given when using time-dosed, pressurized effluent dispersal within 1 foot of the ground surface and more than 1.5 feet above a limiting soil/bedrock condition.

D-2. Ensure wastewater treatment performance effectiveness and cost efficiency by using cluster systems with advanced N-removal technology sufficient to meet the standards specified above for all newly developed communities and densely populated areas.

D-3. Sustain treatment system performance in perpetuity through management contracts with trained and certified operators for all advanced N-removal systems, and responsible management entity (RME) operation and maintenance (O&M) for all cluster and nonresidential systems. RMEs include sanitation districts, special districts, and other public or private entities with the technical, managerial, and financial capacity to assure long-term system performance.

D-4. Preserve long-term treatment system performance with management practices designed to protect system investments, by doing the following:

- Conducting GIS-based inventories of all individual and cluster (i.e., decentralized) wastewater systems in all areas that drain into the Chesapeake Bay or its tributaries. Inventory information includes system location (i.e., latitude/longitude), type, capacity, installation date, owner, and relevant information on complaints, service (including tank pump-out), repairs, inspections, and dates. Inventory data is stored electronically in a format amenable for use in watershed studies, system impacts analyses, and supporting general management tasks. EPA offers *The Wastewater Information System Tool* (TWIST) (USEPA 2006) as a free resource for managing that information in a user-friendly database. Health departments, state agencies, RMEs and others can adapt, amend, or otherwise modify TWIST without restriction or obligation.
- Requiring inspections for all systems on a schedule according to wastewater type, system size, complexity, location, and relative environmental risk. At a minimum, qualified inspectors inspect all systems at least once every 5 years and inspect existing systems within sensitive areas at least once every 3 years. Inspect advanced treatment systems, cluster systems, and those serving commercial, institutional, or industrial facilities at least semiannually and manage such systems under an O&M agreement or by an RME. Inspections are consistent with EPA management guidelines for individual and cluster systems. A service professional or other trained personnel conducts routine monitoring of all systems, and periodic effluent sampling for cluster and nonresidential systems, on the basis of system type, operating history, manufacturer's recommendations, and other relevant factors.
- Repairing or replacing all malfunctioning systems when discovered, with new or replacement technologies capable of meeting the N-removal standards specified above.
- Requiring reserve areas for installing a replacement soil dispersal system that is equal to at least 100 percent of the size of the original effluent

dispersal area. Treatment systems using effluent time-dosing (i.e., not demand-dosing) to the soil can have reserve areas equal to at least 75 percent of the total required drainfield area. Systems with pressurized drip effluent dosing or shallow pressurized effluent dispersal and those with dual drainfields operated on active/rest cycles (i.e., alternating drainfields) can have reserve areas equal to at least 50 percent of the original required dispersal area.

D-5. Remove nitrate in subsurface effluent plumes that enter surface waters by using effective, low-cost technologies such as permeable reactive barriers (PRBs). PRBs are low-cost, pH-controlled trenches filled with sand and a degradable carbon source, such as sawdust, shredded newspaper, or wood chips, designed to intercept groundwater plumes and reduce the TN concentration via denitrification.

2 Introduction and Background

Individual on-site and cluster (*decentralized*) wastewater systems treat household and commercial wastes in suburban, exurban, and rural areas throughout the Chesapeake Bay watershed. The Chesapeake Bay Program (USEPA 2009) estimates that about 25 percent of the homes in the watershed—2.3 million total—rely on these systems, which disperse treated effluent to the soil. EPA predicts that decentralized system installations will increase over the next 20 years by about 35 percent (i.e., 800,000 new systems), eventually reaching 3.1 million (USEPA 2009).

Nearly all the solids and phosphorus (P) discharged from decentralized wastewater systems are retained by the soil, through physical filtration, adsorption, and precipitation processes (USEPA 2004), although release of P into the environment is a concern in sandy soils under certain conditions, especially with poor vertical separation distance with groundwater (Bussey 1996). However, N in wastewater is ultimately converted to nitrate upon infiltration into aerobic soils, a stable, soluble, and highly mobile form of this nutrient that negatively affects groundwater and surface water quality. For those reasons, in this guidance EPA focuses on implementation measures to reduce N.

Decentralized wastewater systems contribute approximately 12.5 million pounds of N to the Chesapeake Bay annually, or about 4.5 percent of the total load. According to current Chesapeake Bay nutrient loading models, most of the N load from such systems—about 60 percent—comes from the Potomac and Susquehanna river drainage areas within Pennsylvania, Virginia, and Maryland. With 800,000 new systems predicted over the next 15 years, significant reductions in N loads from new and existing systems are needed.

The Chesapeake Bay nutrient and sediment reduction goals include decreases in current and future pollutant loads from decentralized treatment systems. A new generation of “hardware and software”—treatment technologies and management practices—are needed to achieve the reductions. This section describes those technologies, management practices, and associated implementation measures. Implementation measures for achieving the reductions include installing treatment units with optimal N-removal capabilities in sensitive areas near surface waters; using standard N-removal systems in other areas; and ensuring that all treatment systems are appropriately operated, maintained, and managed. The measures encompass a range of treatment technologies, planning and performance considerations, and management actions needed to address N export from decentralized systems.

The implementation measures described in this chapter support two primary goals for addressing N inputs to the Chesapeake Bay from these systems:

- Prevent further impairment of the Chesapeake Bay by significantly reducing N levels in wastewater from new residential, commercial, and institutional developments using decentralized systems
- Reduce N inputs to the Chesapeake Bay from existing individual and cluster wastewater systems by replacing malfunctioning systems with better-performing technologies and by managing all systems to ensure long term performance

Implementation measures to achieve those goals include repairing or replacing malfunctioning systems, targeting high-risk systems in sensitive areas for replacement with advanced treatment units, clustering replacement systems where possible to implement better-performing and more efficient community treatment facilities, inspecting all systems throughout the Chesapeake Bay watershed, and installing PRBs where technically and economically feasible to reduce N concentrations in targeted effluent plumes. Those approaches are based on more than 2 decades of research and field studies on decentralized system applications.

Key findings on system performance, effects on groundwater, and the opportunities presented by next-generation treatment technologies are summarized in the *Final Report for the La Pine National Decentralized Wastewater Treatment Demonstration Project* (Rich 2005), a joint effort of EPA and other federal, state, and local agencies:

> The groundwater investigations have found significant existing nitrogen pollution and the 3-D model has predicted extensive future contamination of the aquifer. The model also predicted, based on the field performance of denitrifying systems in the project, that contamination could be slowed or stopped using onsite wastewater treatment technologies, and that, as the region is retrofitted with denitrifying technologies, the existing contamination would be flushed from the groundwater system via existing natural discharge points.
>
> The field test program, in addition to identifying systems that can remove a large proportion of the nitrogen in residential wastewater, found that conventional systems are not protecting the aquifer from nitrate contamination. Conventional systems that were previously thought to denitrify up to 50% of the nitrate discharged from septic tanks were found to achieve significantly less denitrification when process and environmental variables were accounted for.

The La Pine Project, EPA's Environmental Technology Verification (ETV) program, the National Sanitation Foundation standards program, and other research efforts across the country have identified and tested a number of denitrifying wastewater systems and found that performance varies considerably. However, some systems do perform optimally in removing TN from the effluent—e.g., to concentrations lower than 5 mg/L—and others are capable of N effluent levels in the 10 and 20 mg/L range.

Higher treatment performance levels are needed in sensitive areas to protect or restore surface water quality. Research and field studies confirm that effluent plumes with elevated nitrate levels move laterally over long distances—i.e., greater than 300 feet in unconfined, sandy aquifers (Walker et al. 1972; Robertson and Cherry 1992). N concentrations in effluent plumes are affected by soil oxygen levels, soil composition, plant uptake, labile carbon content, travel distance, rate of movement, mixing, and other factors. The measures specified in this chapter include descriptions of treatment and dispersal systems that can meet the performance standards needed to protect the Chesapeake Bay and its tributaries and include more stringent treatment levels in sensitive areas near waterbodies. Such measures are consistent with efforts in the states that have already been adopting treatment zone setbacks and treatment standards to address N and other pollutants in coastal areas (Joubert et al. 2003).

3 Nutrient-Reduction Processes for the Decentralized Wastewater Sector

Nutrients—primarily P and N—are usually present in significant levels in domestic and commercial wastewater. Nutrient treatment and removal involve processes that occur either in treatment system components or in the receiving environment, as summarized below.

3.1 Nitrogen

N is the primary pollutant of concern along the coastal areas of the eastern United States, including the Chesapeake Bay. N discharges are a concern both as a drinking water contaminant (nitrate) and as an aquatic plant nutrient, particularly in N-sensitive surface waters and nearshore marine waters. N is not readily or consistently removed in conventional individual and cluster soil-based systems because conventional soil-discharging systems are not designed to remove N, and most soils have a limited capacity to retain or remove N. Organic N in wastewater is generally converted to ammonium N in the septic tank. Ammonium N is quickly nitrified as the wastewater infiltrates the aerobic soil. Nitrate-N is stable, soluble, and highly mobile in the subsurface environment. Biological denitrification of the nitrate is usually limited because the soil is often aerobic near the ground surface and usually has very little organic carbon, which is required by heterotrophic denitrifying microorganisms. Therefore, where N removal is required for dispersal, pretreatment that achieves both nitrification and denitrification is usually necessary before the wastewater is dispersed to the soil.

3.2 Nitrogen Pretreatment

Many reasonably priced natural and mechanical pretreatment systems, specifically designed for individual and cluster systems, are available today. The most popular example of such systems is the recirculating media filter, with timed pressure-dosing effluent dispersal. The filter media is typically sand, gravel, textile, or peat. A portion of the filtered effluent is recycled back to the septic tank (or pump/recirculating tank) and filter several times before discharge. Denitrification is supported by the low-oxygen, high-carbon environment that exists in the recirculating tank. The systems are able to consistently remove an average of 50 percent or more of the TN in the septic tank effluent—reducing the TN from a typical influent range of 40–50 mg/L for single family homes to 15–20 mg/L (Otis 2007; USEPA 2002a; Jenssen and Siegrist 1990; Higgins et al. 2002; Smith et al. 2008; Rich et al. 2003).

To achieve TN levels of 3–5 mg/L and lower, an additional denitrifying unit process is usually installed to augment the pretreatment system. To sustain a denitrification process capable of high levels of N removal, the nitrified effluent from the pretreatment process must be exposed to a reactive carbon source in a low-oxygen environment before discharge. For larger installations, methanol, acetic acid, molasses, or other organic chemicals are added to the anaerobic reactor. However, the cost of building, operating, and maintaining an external chemical feeding system, coupled with the cost of chemicals, power for a feed pump, controls, and chemical storage increase N-removal expenses substantially.

Carbon sources are not equal in terms of O&M requirements. For example, methanol is very sensitive to under- or over-dosing, and thus requires special attention to ensure that the system is monitored enough to control dosing for optimal N-removal and biochemical oxygen demand control. By contrast, sawdust and newspapers need to be replaced only when effluent N breaks through (i.e., the denitrification capacity of the sawdust or newspaper has been exhausted).

Proprietary denitrifying units, which avoid the need for additional feed pumps, controls, and chemicals, are now available. Such units include a slowly degradable organic material in the reactor tank that can last several years. Field testing has documented TN effluent concentrations of 3–5 mg/L and even lower (Smith et al. 2008; Lombardo et al. 2005).

Further N removal occurs in the soil, particularly when pretreated effluent is dispersed uniformly via alternating dose/rest cycles. Plant uptake of N, soil oxygen levels, carbon sources, temperature, and residence time are key factors in N-removal levels during this final stage of treatment, which are estimated in the 50 percent reduction range (Long 1995; Otis 2007). Additionally, some soils contain sufficient labile carbon to denitrify effluents regardless of the method of dispersal (Anderson 1998; Gold et al. 2002; Starr and Gillham 1986; Bushman 1996; Hiscock et al. 1991). Other important variables could include seasonal use (Postma 1992), in-stream processes, including the matrix through which the groundwater enters nearby surface waters (Birgand 2000; Stewart and Reneau 1984), and the distance from the source to the receiving surface waters (Stacey 2002). One study from the U.K. (Hiscock et al. 1991) estimates that average groundwater carbon content would account for removal of 3 mg/L of nitrate.

3.3 Phosphorus

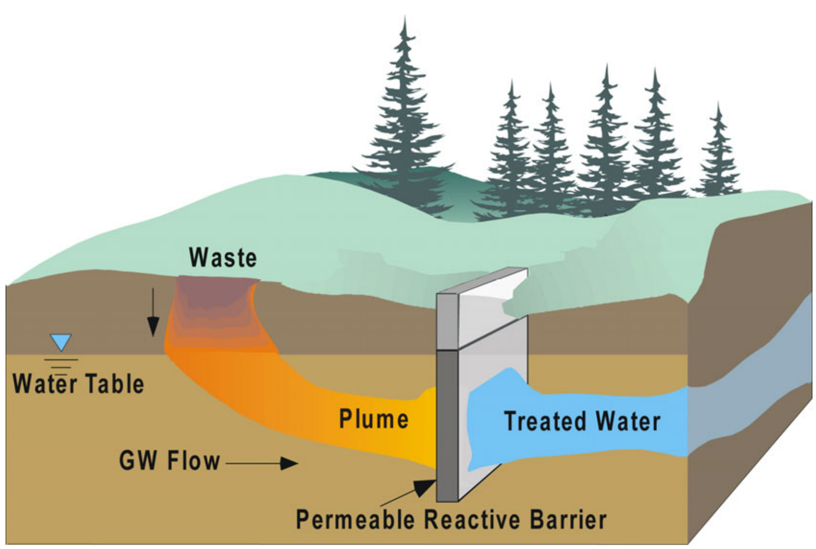
Approximately 20 to 30 percent of the P in wastewater is removed in septic tanks (Lombardo 2006). P removal in soil effluent dispersal systems is achieved primarily by mineral precipitation. The process involves sorption and complex biogeochemical mechanisms that rely on dissolved P mineralization with iron, calcium, and aluminum (Tyler et al. 2003; Stone Environmental 2005; Lombardo 2006). The stability of those processes is influenced by pH, redoximorphic conditions, and the chemistry of aluminum and iron. The soil's capacity to remove P is significant both spatially and temporally. Sorption can be reversible—as with sands, or relatively permanent, as in soils high in iron oxides.

In general, most regions of the Chesapeake Bay watershed have soils that retain high levels of P from decentralized systems. Areas where soil-based, P-removal rates are low include highly permeable soils, such as sands, loamy sands, and soils very high in gravel. In areas with sufficient soil P-removal capacity, saturation fronts of P move only inches or less per year. Wastewater system designers maximize P-removal rates by locating the infiltration system in medium- to fine-textured soils that are as far from surface waters as possible, and extending the infiltration system along the topographic contour of the installation site. Also, uniform dosing and resting dispersal by pressure or drip distribution will optimize P removal in the soil by increasing the contact time between the effluent and the soil.

If native soils are not amenable to adsorption removal, other adsorption methods are available (Stone Environmental 2005; Dimick et al. 2006; USEPA 2002a). Although some P can be removed by pretreatment systems that contain high concentrations of adsorptive elements or by biological P removal, soil adsorption is by far the most common and least expensive means of removal. Where soils are inadequate for P removal, mound systems that use more appropriate soil (possibly imported) might be required. System use over time slowly reduces the capacity of the soil to remove P.

3.4 Permeable Reactive Barriers

Specific types of PRBs have been developed to remove nitrate from groundwater plumes that would otherwise adversely affect surface water quality. PRBs consist of a trench filled with a degradable carbon source (e.g., sawdust, newspaper) and are sited to intercept high-nitrate groundwater plumes (WE&T 2009) before they enter surface waters (Figure 6-1). As the plumes pass through the low-oxygen, carbon-rich barrier, bacteria break down nitrate molecules to use the oxygen for cell respiration. In areas where receiving waters are already eutrophied, the trenches provide immediate relief by removing nitrate from the incoming groundwater. Addressing the source of the high-nitrate plume (i.e., densely sited septic systems) would also produce results, but any measureable effects would likely take several years



Source: USEPA 1998

Figure 6-1. PRB conceptual approach.

because of slow effluent plume movement in most soils and could be more expensive and require more maintenance than installing PRBs.

PRBs are typically installed as long, narrow trenches perpendicular to the incoming plume and parallel to the shoreline. The most effective ones for removing nitrate from plumes are filled with a carbon-based media mix that controls for changes in pH. Such systems have been successfully demonstrated in North America and Europe (Vallino and Foreman 2008; Robertson and Cherry 1995; Lombardo et al. 2005; USEPA 1998). Costs range from about $5,000 to $15,000 per equivalent dwelling unit (i.e., in the plume sourcing area), depending on soils, geology, depth to groundwater, subsurface hydrology, construction access, existing infrastructure, and other factors. Zero valent iron, now used for some industrial wastewater treatment applications, has been studied as a nutrient-removal media in PRBs and other system components. Obstacles with this technology include reduction of nitrate to ammonia rather than N gas and relatively high costs (Cheng 1997). New variations of this technology hold promise for removing some of these obstacles (Lee et al. 2007).

3.5 System Configuration

As noted above, a certain level of treatment process sophistication and soil discharge technique (e.g., pressure dosing, drip dispersal) are required for optimum N removal. Their cost in terms of both hardware and management needs can be significantly mitigated through the use of cluster systems that treat wastewater from multiple homes or businesses. Cluster systems, also called community or distributed systems, have become extremely popular in areas where high levels of wastewater treatment are required, where space is too limited for on-site conventional soil-discharging systems, and local funding capacity precludes conventional sewage collection and treatment (see Section 4.6).

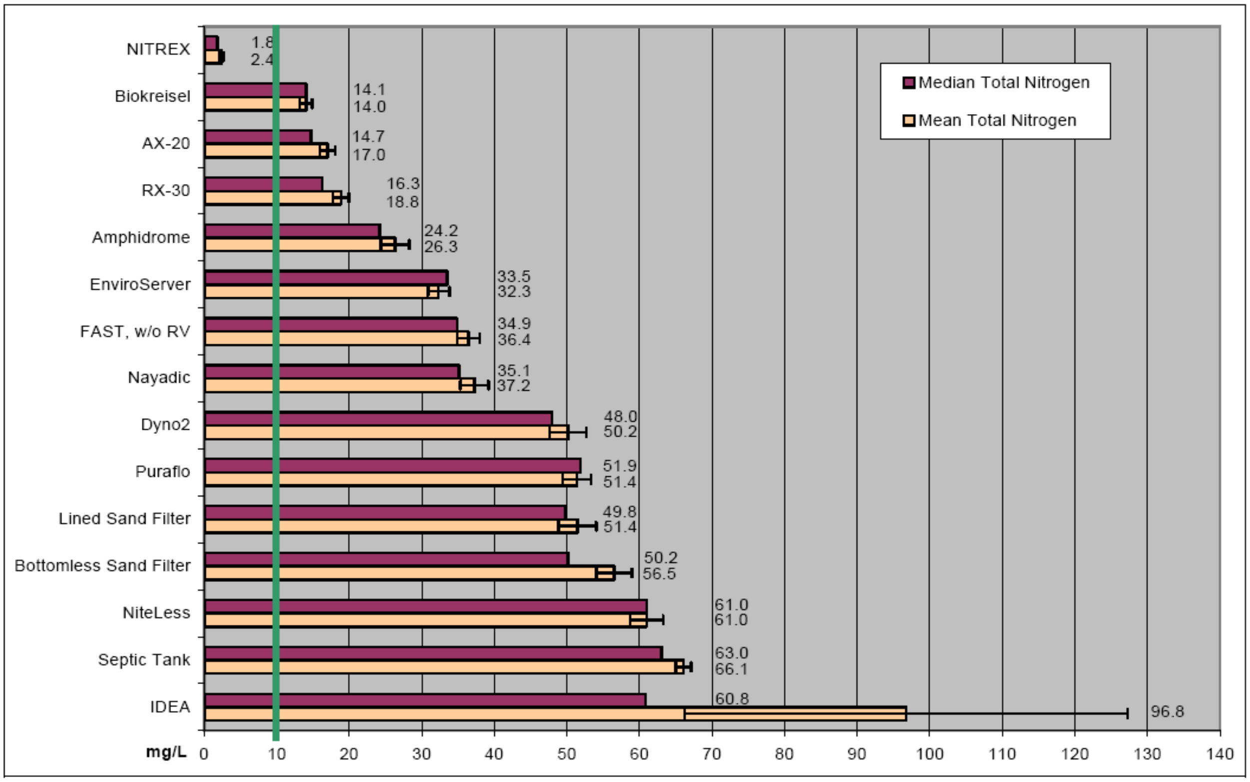
It should be noted that soil-discharging wastewater systems that have the capacity to serve 20 or more people per day are defined by EPA as Class 5 underground injection wells and are therefore subject to permitting and other requirements for large-capacity septic systems under the federal Safe Drinking Water Act. Further, any decentralized system that accepts waste other than sanitary wastewater (such as industrial waste) is an Underground Injection Control (UIC) Class 5 Injection Well. UIC regulatory information for large-capacity septic systems is posted at http://www.epa.gov/safewater/uic/class5/types_lg_capacity_septic.html.

4 Treatment Technologies and Costs

Key considerations in treatment system selection are wastewater flow, strength (i.e., biochemical oxygen demand), the presence of nonconventional organic or inorganic constituents, the sensitivity of the receiving environment, and the capacity of system managers to operate and maintain it over the long term. Given those factors, both the *selection* and ongoing *use* of a specific technology is driven by management considerations. For example, wastewater characterization and assessment of the receiving environment are planning-level activities that result in establishing performance standards, which begin to identify the narrow range of treatment technology options and related design considerations. Once a specific system is selected, construction oversight, operation, inspection, maintenance, and residuals removal—all management program elements—become paramount in ensuring perpetual performance.

The La Pine Decentralized Wastewater Demonstration Project (Rich 2005) has provided some of the most comprehensive field data on the performance of various system types. The project—funded by EPA and supported by the Deschutes County, Oregon, Environmental Health Division; Oregon Department of Environmental Quality; and the U.S. Geological Survey—monitored system performance between 1999 and 2005 (see Figure 6-2 and Table 6-1). System performance was found to be affected by a number of variables, but in general the level of analysis provides insight on the range of pollutant removal that can be expected from the various system types. The figure and table that follow summarize key data from the project; detailed performance results, system descriptions, and other information are available in the final project report (Rich 2005).

The subsections that follow discuss the main classes of treatment system technologies. The final section of this chapter summarizes management program elements that support the implementation measures provided at the beginning of this chapter. Table 6-2 provides examples of biological N-removal performance from the literature for a variety of technologies. Table 6-3 contains details on specific treatment systems described in the subsections below.



Source: Rich 2005.

Figure 6-2. Effluent TN concentrations for systems tested in the La Pine Project.

Table 6-1. System components and type classifications for Figure 6-2

System component/type	General classification
Septic Tank	Primary treatment vessel
Lined Sand Filter	Attached growth, sand media
Bottomless Sand Filter	Attached growth, sand media
AdvanTex AX-20	Attached growth, textile media
AdvanTex RX-30	Attached growth, textile media
Puraflo	Attached growth, peat media
Dyno2	Attached growth, gravel media, wetland polishing
Amphidrome	Attached growth/suspended growth hybrid
Biokreisel	Attached growth/suspended growth hybrid
EnviroServer	Attached growth/suspended growth hybrid
FAST Bio-Microbics	Attached growth/suspended growth hybrid
IDEA	Suspended growth
Nayadic	Suspended growth
NiteLess	Suspended growth with add-on anoxic filter
NITREX	Add-on anoxic filter

4.1 Conventional Systems

Conventional treatment systems featuring septic tanks and soil infiltration systems are the most commonly used wastewater treatment technologies. The soil dispersal system facilitates aerobic treatment, degradation, filtration, and adsorption of contaminants not treated or retained by the septic tank. However, N removal is somewhat limited, with TN concentrations before soil application typically in the 40–50 mg/L range. In sandy soils with little organic content, high oxygen levels, and poor downgradient mixing, N concentrations can remain high even after several hundred feet of effluent plume movement (Walker et al. 1973; Robertson and Cherry 1992; Cogger 1988; Joubert et al. 2003). Given the low N-removal rates of conventional systems (i.e., averaging 20 percent TN removal; Otis 2007; Smith et al. 2008; Jenssen and Siegrist 1990), they are no longer appropriate for use in new communities or densely developed areas in the Chesapeake Bay watershed.

4.2 Land/Vegetative Treatment Systems

Land treatment systems, such as spray irrigation systems, are permitted in some places but have not been widely used because of their large land area requirements (USEPA 2000). In general, such vegetative treatment systems have shown poor performance with regard to N removal. However, in recent years, significant advances have been made. The Living Machine, a proprietary decentralized wastewater treatment system has been used successfully for large-capacity applications, such as schools. While the system delivers advanced N removal, it relies on multiple treatment processes including anaerobic and aerobic reactors, a clarifier, and an *ecological fluidizer bed* (USEPA 2002b), which drive up the cost. Eco-machines are similar in concept to The Living Machine and are capable of advanced N removal. Costs for both of these technologies make sense for only fairly large-capacity applications. They are not practical for individual residential systems but could be useful for cluster and large system applications.

4.3 Suspended Growth Systems

Suspended growth systems, such as activated sludge-based aerobic treatment units (ATUs), are generally effective in nitrifying septic tank effluent. Denitrification is somewhat limited but can be aided by process controls (e.g., recirculation) and effluent dispersal via time-dosing into the upper soil horizon (Stewart 1988). Aerobic units that feature aeration that periodically stops and starts show improved denitrification. Sequencing batch reactors, which first fill and then draw, in alternating aerobic/anoxic cycles in a single tank might also meet the 20 mg/L recommended effluent limit for areas more than 1,000 feet from surface waters in the Chesapeake Bay watershed, when effluent is dispersed to the soil via time-dosed pressure application (Washington State Department of Health 2005). Capital costs for conventional on-site suspended growth systems range from $7,500 to $15,000 per equivalent dwelling unit

(EDU), with O&M expenses of $400 to $800 per EDU per year when all suggested O&M tasks are performed (Tetra Tech 2007).

N removal in larger cluster applications of suspended growth systems (i.e., > 200 homes) can be enhanced by incorporating a membrane bioreactor process (MBR) unit, which screens wastewater through very small pore-size filters. MBRs are more common to centralized treatment facilities because of operating costs and economy of scale issues. However, individual home-sized and small cluster units are beginning to be developed for the U.S. market (e.g., BioBarrier, ZeeWeed; WERF 2006). The high-quality effluent provides opportunities for treated water reuse. Cost and performance data for individual and small cluster applications of MBRs are not widely available and are likely to vary greatly. Energy costs, particularly to operate the pumping components, are often significant, especially in smaller system applications (USEPA 2007).

4.4 Attached Growth Aerobic Systems

These systems (sometimes called trickling filters or media filters) use natural aeration instead of mechanical, produce less sludge for disposal, and require less power and O&M than the suspended growth units in performing the same tasks. All the systems listed in Table 6-3 are varieties of attached growth system types. Like suspended growth systems, attached growth treatment units also require a recirculation step to meet more stringent TN-removal objectives. Commercially available systems come in lightweight packages and employ lightweight media for easy installation. They also require about 20 percent less physical footprint than typical trickling filters. When properly loaded and operated, they can produce very high nitrification levels that must be followed by a denitrification step to exceed the typical 50 percent N-removal rate. Attached growth systems are also often quite stable compared with suspended growth processes, which might be important, particularly for decentralized systems serving periodically or seasonally used facilities. On-site capital costs are slightly higher in general than the suspended growth ATUs ($10,000–$16,000 per EDU), but O&M costs are significantly less, e.g., about $200–$300 per EDU per year (USEPA 2010; Tetra Tech 2007).

N removal in attached growth media filters can be optimized through internal treatment system process controls. Single-pass media filters—sand filters, textile filters, peat systems, mounds, and other packed media bed units—achieve excellent nitrification levels but generally do a poor job with denitrification unless some, or all, of the effluent passes through a carbon-rich, low-oxygen environment after the nitrification stage. That can be accomplished by recirculating a portion of the effluent back to the septic tank or a pump tank, or by adding a denitrification unit to the system, or both. Media filters have a long record of excellent performance, with nitrification rates as high as 95 percent (Otis 2007; Smith et al. 2008; USEPA 2002a). The treatment process is stable year-round and can be employed through either custom-built, nonproprietary engineered systems or commercial units that can be installed in a single day. Capital costs for single-pass filters range from $5,500 to $13,000 per EDU, with O&M expenses of $200 to $400 per EDU per year (USEPA 2010; Tetra Tech 2007).

Recirculating media filters have been in use for many years and feature high nitrification rates with about 50–70 percent TN reduction. The systems recycle part of the effluent back to the septic tank or the recirculating tank, where the anoxic environment and available carbon facilitate denitrification processes. Design considerations include the ratio of effluent recirculated and the configuration of the recycle plumbing, i.e., ensuring that the recycled effluent is discharged to a tank location with low oxygen and some carbon. TN effluent concentrations can be as low as 10 mg/L, which can be further reduced in the soil by using time-dosed, pressure-drip effluent dispersal. Engineered systems and proprietary units are widely available and can serve single homes or large subdivisions. Capital costs for recirculating systems range from $9,500 to $20,000 per EDU, with O&M expenses of $350 to $600 per EDU per year (USEPA 2010; Tetra Tech 2007; Washington State Department of Health 2005).

4.5 Add-On Anoxic Filters with a Carbon Source

Optimal denitrification can be achieved by passing nitrified effluent through a low-oxygen, carbon-rich environment before soil dispersal. Engineered and proprietary systems featuring add-on anoxic filters with an external carbon source (e.g., methanol, sawdust, newspapers) have performed successfully in single-home and cluster applications. For example, at least one commercially available product (NITREX) regularly produces effluent with N concentrations of less than 5 mg/L (Heufelder et al. 2007, see also Figure 6-2 and Table 6-2). Others claim to have similar systems with comparable performance, although, to date, independent field verification is lacking. NITREX relies on a passive nitrate remediation biofilter unit that uses a processed wood by-product as the filter medium. Other system designs discussed above can approach that level when paired with time-dosed, shallow pressurized dispersal. Capital costs for add-on denitrification systems range from $3,500 to $7,000 and more per EDU, with O&M expenses of less than $100 per year (Washington State Department of Health 2005). Note that those are added costs and do not include costs for the septic tank, nitrification process unit, or soil dispersal system—just the add-on component.

Table 6-2. Examples of biological N removal performance from the literature

Technology examples	TN removal efficiency (%)	Effluent TN (mg/L)
Suspended growth		
Aerobic units w/ pulse aeration	25%–61%[a]	37–60[a]
Sequencing batch reactor	60%[b]	15.5[b]
Attached growth		
Single-Pass Sand Filters (SPSF)	8%–50%[c]	30–60[c]
Recirculating Sand/Gravel Filters (RSF)	15%–84%[d]	10–47[d]
Multi-Pass Textile Filters (AdvanTex AX20)	64%–70%[e]	3–55[e]
RSF w/ Anoxic Filter	40%–90%[f]	7–23[f]
RSF w/ Anoxic Filter & external carbon source	74%–80%[g]	10–13[g]
RUCK system	29%–54%[h]	18–53[h]
NITREX	96%[i]	2.2[i]

Source: Adapted from Washington Department of Health 2005

Notes: Overall performance can vary, depending on system configuration and other factors. For detailed descriptions of treatment processes and technologies, see http://www.psparchives.com/publications/our_work/hood_canal/hood_canal/n_reducing_technologies.pdf.

a. California Regional Water Quality Control Board 1997; Whitmeyer et al. 1991

b. Ayres Associates 1998

c. Converse 1999; Gold et al. 1992; Loomis et al. 2001; Nolte & Associates 1992; Ronayne et al. 1982

d. California Regional Water Quality Control Board 1997; Gold et al. 1992; Loomis et al 2001; Nolte & Associates 1992; Oakley et al. 1999; Piluk and Peters 1994; Ronayne et al. 1982

e. NSF International 2009

f. Ayres Associates 1998; Sandy et al. 1988

g. Gold et al. 1989

h. Brooks 1996; Gold et al. 1989

j. Rich et al. 2003

4.6 Composting Toilet Systems

Composting toilet systems that contain and treat toilet wastes can reduce watershed N discharges significantly, because such wastes account for 70–80 percent of the TN load in domestic wastewater. Composting systems have been used successfully in both private and public facility settings. Like all systems, they require appropriate design and ongoing maintenance. A graywater treatment system is needed if the facility generates sink, laundry, or other graywater, therefore adding to the cost. Capital costs for composting systems (and excluding the cost of graywater systems) range from $2,500 to $10,000, with O&M expenses of $50 to $100 per year (USEPA 1999). The single-house viability of such systems depends on local codes and the owner's attitude, though acceptance and use of composting systems is increasing because of improved designs, performance, and lower maintenance requirements. The systems are more frequently used in public settings, such as parks and campgrounds.

4.7 Cluster Treatment Systems

Generally, cluster systems collect wastewater from multiple houses through low-cost sewerage and treat and disperse the effluent to soil-based dispersal systems similar to on-site systems. Many homes and businesses can be served by a single treatment facility. Most cluster systems feature septic tanks on each building lot; collection piping that operates via gravity, vacuum, or pressure; a treatment facility with attached growth process units; and a soils-based dispersal field for the effluent. Add-on anoxic denitrification filters can be included. Effluent is typically dispersed to the soil under pressure (e.g., pressure, drip, time or demand dosing) to assure uniform application throughout the larger drainfield. Collection technologies include grinder pump systems, which macerate and transport all sewage; effluent sewers, such as the septic tank effluent pump (STEP); the septic tank effluent gravity (STEG) collection system; and vacuum systems.

Advanced treatment systems can facilitate local reuse of the treated effluent for toilet flushing, irrigation, industrial purposes, or just be used to replenish aquifers. The cost of a cluster collection system varies significantly according to the number of users, collection system logistics, treatment facility design, land availability, materials, labor costs, and other factors. Cluster systems can achieve economies of scale to provide high levels of treatment at costs significantly less than individual systems and centralized sewer systems. New cluster systems generally range from $10,000 to $18,000 per EDU in non-urbanized areas of new development, with higher costs for retrofits in urban areas, depending on the treatment technology used (USEPA 2010; Tetra Tech 2007). Replacement and retrofit systems have similar costs, but collection system installation can drive costs higher. An RME with the technical, financial, and managerial capacity to ensure viable, long-term, cost-effective performance is essential for cluster system applications. Total system annual O&M costs range from $450 to $750 per EDU per year (Tetra Tech 2007).

4.8 Soil Dispersal Systems

Gravity-based, soil dispersal systems generally include conventional perforated pipe, laid in stone-filled trenches or purchased with Styrofoam beads surrounding the pipe and wrapped in netting; and gravelless, open-bottomed leaching chambers. N removal in the soil increases when effluent is dispersed in a time-dosed manner (i.e., dose/rest cycle) in the uppermost soil horizon (i.e., within one foot of the ground surface). Time-dosed, pressure-drip dispersal in the top 12 inches of soil has been credited with a 50 percent reduction in Tennessee (Long 1995), making the option an important feature for achieving the performance standards recommended in this chapter. As in all effluent dispersal systems, maximizing the separation distance between effluent application and restrictive soil boundaries (e.g., hardpan, bedrock, perched water tables, seasonal high water tables) improves performance.

Another effluent-dispersal strategy that improves performance is the use of alternating soil dispersal fields. Most conventional systems continuously load drainfields with effluent, resulting in a gradual reduction of the soil's capacity to treat effluent over time. Alternating drainfields that are used for 6 months then rested for 6 months improves the performance of the soil dispersal system and should be favored over conventional drainfields. Such systems require relatively low additional investment and can greatly extend the life of the soil dispersal system (Noah 2006). Maintenance programs for such systems should be designed and implemented in concert with the local health department or RME to ensure that flow-diversion devices are operated on schedule. Because this strategy applies to conventional septic drainfields, this recommendation applies primarily to areas of new development outside sensitive areas and subdivisions.

4.9 Effluent Reuse

Reusing treated wastewater system effluent can significantly reduce N discharge to the environment. Many of the technologies suggested for advanced decentralized wastewater treatment in the Chesapeake Bay watershed can, with adaptations, be used to produce reclaimed water for beneficial reuses, including aquifer recharge, landscape irrigation, toilet flushing, fire protection, cooling and other nonpotable indoor and outdoor purposes (USEPA 2004). When reclaimed water is used for irrigation, reuse can offset potable water demand by augmenting supply while sequestering nutrients in vegetative matter and offsetting fertilizer use (WERF 2010). Reclaimed water technologies generally include recirculating filtration systems and membrane bioreactors, amended with disinfection systems (most commonly, chlorination or ultraviolet disinfection or both), online monitoring systems, on-site storage, and sometimes specific chemical feed systems for conditioning treated effluent to meet water quality demands for specific reuses (e.g., pH adjustment for cooling water). Nonreactive dye injection is sometimes required by building codes for reclaimed water to be used indoors. Costs for decentralized reclaimed water systems are highly context-specific and dependent on the intended reuse application, system size, and local or state regulatory requirements (WERF 2010) but can be assumed to add 50 percent to the costs of a more traditional decentralized system.

Table 6-3. Products that have completed the EPA ETV process for N reduction in domestic wastewater from individual homes, as of May 2005

System name	Technology	Description of process	Performance	Cost
Waterloo Biofilter® Model 4-Bedroom Waterloo Biofilter Systems, Inc. 143 Dennis St.: P.O. Box 100 Rockwood, Ontario Canada N0B 2K0 http://www.nsf.org/business/water_quality_protection_center/pdf/Waterloo-VS-SIGNED.pdf	Fixed film trickling filter.	The biofilter unit uses patented lightweight open-cell foam that provides a large surface area. Settled wastewater from a primary septic tank is applied to the surface of the biofilter with a spray distribution system. The system can be set up using a single pass process (without any recirculation of biofilter treated effluent) or can use multi-pass configurations. The ETV testing results were generated by returning 50% of the biofilter effluent back to the primary compartment of the septic tank.	It averaged 62% removal of TN with an average TN effluent of 14 mg/L over the 13-month testing period. Earlier testing of this product in a single pass mode demonstrated that it could produce a 20–40% TN reduction.	$13,000–$17,000 for total system installation. The Waterloo Biofilter unit only would cost approximately $7,000.
Amphidrome™ Model Single Family System F.R. Mahony & Associates, Inc. 273 Weymouth St. Rockland, MA 02370 http://www.nsf.org/business/water_quality_protection_center/pdf/Amphidrome_VS.pdf	Submerged growth sequencing batch reactor (SBR) in conjunction with an anoxic/equalization tank and a clear well tank for wastewater treatment	The bioreactor consists of a deep bed sand filter, which alternates between aerobic and anoxic treatment. The reactor operates similar to a biological aerated filter, except that the reactor switches between aerobic to anoxic conditions during sequential cycling of the unit. Air, supplied by a blower, is introduced at the bottom of the filter to enhance oxygen transfer.	It averaged 59% removal of TN effluent of 15 mg/L over the 13-month testing period at the Massachusetts Alternative Septic System Test Center (MASSTC).	$7,500 for unit only. The manufacturer estimates it would cost $12,000–$15,000 for a complete installation.
SeptiTech® Model 400 System SeptiTech, Inc. 220 Lewiston Road Gray, ME 04039 http://www.nsf.org/business/water_quality_protection_center/pdf/SeptiTech_VS.pdf	Two-stage fixed film trickling filter using a patented highly permeable hydrophobic media	Clarified septic tank effluent flows by gravity into the recirculation chamber of the SeptiTech unit. A submerged pump periodically sprays wastewater onto the attached growth process and the wastewater percolates through the patented packing material. Treated wastewater flows back into the recirculation chamber to mix with the contents. Treated water flows into a clarification chamber and is periodically discharged to disposal unit (drainfield, drip irrigation, etc.)	Averaged 64% removal of TN with an average TN effluent of 14 mg/L over the 12-month testing period at MASSTC.	$11,000 for SeptiTech unit includes shipping and installation. The manufacturer estimated that a total system with pressure distribution drainfield would cost approximately $20,000.

Table 6-3. Products that have completed the EPA ETV process for N reduction in domestic wastewater from individual homes, as of May 2005 *(continued)*

System name	Technology	Description of process	Performance	Cost
Bioclere™ Model 16/12 Aquapoint, Inc. 241 Duchanine Blvd. New Bedford, MA 02745 http://www.nsf.org/business/water_quality_protection_center/pdf/Bioclere-VS-SIGNED.pdf	Fixed film trickling filter.	Septic tank effluent flows by gravity to the Bioclere clarifier unit from which it is sprayed or splashed onto the fixed film media. Treated effluent and sloughed biomass are returned to the clarifier unit. A recirculation pump in the clarifier periodically returns biomass to the primary tank. Oxygen is provided to the fixed film by a fan located on the top of the unit.	Averaged 57% removal of TN with an average TN effluent of 16 mg/L over the 13-month testing period at MASSTC.	$7,500 for unit itself. Price for total system would need to include primary septic tank, Bioclere unit and disposal option, with costs in the range of $12,000–$15,000. The manufacturer recommends use in clusters to reduce per home costs and facilitate maintenance. Experience with a 27-home cluster resulted in costs of $6,800– $8,000 per home.
Retrofast 0.375 System Bio-Microbics 8450 Cole Parkway Shawnee, KS 66227 http://www.nsf.org/business/water_quality_protection_center/pdf/Biomicrobics-FinalVerificationStatement.pdf	Submerged attached-growth treatment system, which is inserted as a retrofit device into the outlet side of new or existing septic tanks.	The RetroFAST 0.375 System is inserted into the second compartment of the septic tank. Air is supplied to the fixed film honeycombed media of the unit by a remote blower. Alternate modes of operation include recirculation of nitrified wastewater to the primary settling chamber for denitrification. Intermittent use of the blower can also be programmed to reduce electricity use and to increase nitrification.	Averaged 51% removal of TN with an average TN effluent of 19 mg/L over the 13-month testing period at MASSTC.	Product and installation cost for the Retrofast 0.375 System ranges is estimated to be $4,000–$5,500 depending on existing tankage. That cost includes the FAST unit, blower, blower housing and control panel. The local representative for Bio-Microbics units believes costs could be as low as $3,500 for multiple units.
Recip® RTS-500 System Bioconcepts, Inc. P.O. Box 885 Oriental, NC 28571-0885 http://www.nsf.org/business/water_quality_protection_center/pdf/Bioconcepts_Verification_Statement.pdf	Fixed film filter	This is the newest product to complete ETV Program testing. It is a patented process developed by the Tennessee Valley Authority (TVA) and uses a fixed film filter medium contained in two adjacent, equally dimensioned cells. Timers on each of the two reciprocating pumps control the process.	Averaged 58% removal of TN with an average TN effluent of 15 mg/L over the 12-month testing period at MASSTC.	Very limited experience with this single-family unit. The unit built for ETV testing was a prototype. The cost per unit, by itself, is estimated to be $8,000–$10,000. Cost of the septic tank and disposal unit would be extra and the cost would depend on site conditions. Conservatively, cost for a total system could be $11,000–$15,000.

Source: Adapted from Washington Department of Health 2005

5 Wastewater Planning and Treatment System Management

The previous section describes N-removing individual or cluster wastewater system technologies, system configurations, and effluent dispersal options. This section describes management considerations that are essential for optimizing treatment system selection, sizing, performance, and long-term use, such as inventory systems, wastewater planning, performance standards, siting and installation guidelines, operation, inspection, maintenance, and residuals handling. The management tasks described in this section are paramount for reducing nutrient inputs to the Chesapeake Bay because they establish the framework for selecting and using specific treatment systems in particular locations. For example, advanced cluster systems are the best approach for protecting and restoring the Chesapeake Bay when considering wastewater facilities for new subdivisions and replacing significant numbers of malfunctioning systems in existing subdivisions.

The following subsections summarize key management program elements viewed as important for controlling the input of nutrients and other pollutants to the Chesapeake Bay. EPA has provided extensive guidance, case studies, resources, references, and links on these management program topics (USEPA 2005, 2010). Specific, detailed information on each topic below is provided in EPA's (2005) *Handbook for Managing Onsite and Clustered (Decentralized) Wastewater Treatment Systems,* available online at http://cfpub.epa.gov/owm/septic/septic.cfm?page_id=289.

5.1 Public Education and Involvement

Decentralized wastewater management programs require public support. The success of such programs will depend on how well homeowners, system service providers, and other stakeholders are involved in the development process. Unless people understand the need for a management program, there is little chance it will be adopted. Once in operation, the program must keep the community engaged, involved, and informed. Managers should give special consideration to explaining the need for new requirements for system upgrades, inspections, or other performance measures.

EPA has partnered with a variety of nonprofit organizations involved in decentralized wastewater management to improve public education, outreach, and involvement through development of informational materials, technical products, and training programs. Links to these partner organizations and the educational, technical, and other resources they provide are provided at http://cfpub.epa.gov/owm/septic/septic.cfm?page_id=260. EPA maintains a repository of print, radio, and TV public service announcements and other materials specifically pertaining to septic system education in its Nonpoint Source Outreach Toolbox, online at http://www.epa.gov/nps/toolbox/.

5.2 Planning

Planning can be used to integrate management strategies for areas served by both centralized and decentralized wastewater treatment facilities, serve as the basis for ordinances and subdivision regulations, and synchronize the community growth plan in harmony with the water and wastewater infrastructure investments. Integrating wastewater planning functions provides better long-term management of facilities and can help local officials deal with a number of needs such as sewer overflows, National Pollutant Discharge Elimination System effluent limitations, total maximum daily loads (TMDLs), and antidegradation requirements. For example, integrated planning can minimize problems associated with competition for infiltration areas between wastewater and stormwater management facilities in new developments, and is useful in anticipating and preventing adverse water quality effects. Variables to consider during the planning process include wastewater flows, proximity and uses of nearby water resources, landscape topography, hydrology, hydrogeology, soils, environmentally sensitive areas, infrastructure system options and locations, population densities, and need and potential for clustering treatment or reuse facilities.

EPA supports a wide range of water resource planning and management functions through programs such as the Clean Water Act section 319 nonpoint source management program, the Clean Water Act 305(b) assessment reports, TMDLs, wellhead and source water protection programs, watershed planning initiatives, coastal management, National Estuary Program, wetlands protection programs, water quality standards, continuous planning processes under section 303(e), water quality management processes under section 205(j) and 604(b), the Clean Water State Revolving Fund, and so on. Ideally, the planning and management activities supporting decentralized wastewater treatment would be integrated, or at least coordinated, with these and other water resource programs, many of which the states operate.

5.3 Performance Requirements

Performance requirements for systems are necessary to minimize the risks they pose to health and water resources. Performance requirements specify objectives for each wastewater management system, which can include physical, chemical, and biological process components. Performance compliance is based on pollutant-removal estimates for the various system components (e.g., septic tank, suspended-growth or fixed-film reactors, lagoons, wetlands, soil, disinfection), verified by periodic field inspections and sampling. Performance can be measured via numeric or narrative criteria. Numeric criteria reflect time-based, mass loadings or pollutant-concentration limits designed to protect sensitive water resources. Pollutants commonly targeted in performance requirements include nutrients, bacteria, oxygen demand, and solids.

5.4 Recordkeeping, Inventories, and Reporting

System inventories provide the nuts and bolts for on-site management. Basic system information—location, type, design capacity, owner, installation, and servicing dates—is essential to an effective program. The best record-keeping programs feature integrated electronic databases with field unit data entry (i.e., using a handheld personal digital assistant), save-to-file computer assisted design drawings, user-specified reporting formats, and GIS-based spatial data management and user interface systems.

5.5 Financial Assistance and Funding

Financial assistance might be needed to (1) develop or enhance a management program; (2) provide support for constructing and modifying wastewater facilities; and (3) support operation of the program. Funding for program development and operation is often available from public and private loan or grant sources, supplemented by local matching funds. It can also be derived from some form of resource sharing among management program partner organizations such as planning departments or health and water resource agencies. Developing an RME and financing for constructing and operating facilities require larger investments that might come from grants and loans or public-private partnerships. Long-term operating costs are usually borne by system users through payment of fees and assessments.

5.6 Site Evaluation

Evaluating a proposed site in terms of its environmental conditions, physical features, and soil characteristics provides the information needed to size, select, and locate an appropriate wastewater treatment system. Regulatory authorities issue installation permits on the basis of the information collected and analyses performed during the site evaluation. Prescriptive site evaluation, design, and construction requirements are based on experience with conventional septic tank/soil dispersal systems and empirical relationships that have evolved over the years. A soil analysis to a depth of 4 to 6 feet using a hand auger, drill rig, or a backhoe pit, rather than a simple percolation test, provides a better approach for assessing soils, seasonal water table fluctuations, and other subsurface site features. Performance-based approaches require a more comprehensive site evaluation. Site evaluation protocols can include some presently employed empirical tests, specific soil properties tests, and soil pits to characterize soil horizons, mottling, and a variety of other properties. Modeling groundwater and surface water impacts of multiple systems in defined areas (e.g., stream subwatershed) can help to further refine performance requirements and related system site and design considerations.

5.7 System Design

Decentralized wastewater treatment system design requirements focus on protecting public health and water resources. However, systems should also be affordable and aesthetically acceptable. Prescriptive codes that specify standard designs for sites meeting minimum criteria simplify design reviews, but they limit development options and the potential for efficiently meeting performance requirements. Where management programs rely on the state code for design, there might not be any need for special review procedures for alternative system designs. However, in sensitive environments where performance codes are employed, there is a need to include allowances for alternative designs even if they only expand the number of prescriptive system choices and site parameters for sites that do not meet the conditions for conventional systems. Design considerations should address the potential implications of water conservation fixtures, effects of different pretreatment levels on hydraulic and treatment performance of soil-based systems, and the O&M requirements of different pretreatment and soil dispersal technologies.

5.8 Construction/Installation

Poor installation can adversely affect performance of both conventional and advanced systems that rely on soil dispersion and treatment. Most jurisdictions allow installation or construction to begin after issuance of a construction permit, which occurs after the design and site evaluation reports have been reviewed and approved. Performance problems linked to installation/ construction are typically related to soil wetness during construction, operation of heavy equipment on soil infiltration areas, use of unapproved construction materials (e.g., unwashed aggregate containing clay or other fines), and overall construction practices (e.g., altering trench depth, slope, length, location). The effects of improperly installed soil-based systems generally occur within the first year of operation in the form of wastewater backups. Some improper construction practices might not be as evident and could take years to manifest themselves in the form of degraded groundwater or surface water. The regulatory authority or other approved professionals should conduct inspections at several stages during the system installation process to ensure compliance with design and regulatory requirements.

5.9 Operation and Maintenance

O&M is important for all wastewater treatment systems, especially those that rely on components that are difficult to remedy if damaged—such as a soil dispersal system. Most system user information includes building awareness of inputs that might affect treatment processes, such as strong cleaners, lye, acids, biocides, paint wastes, oil and grease, and the like. Gravity-flow, soil-infiltration systems require little O&M beyond limiting inputs to normal residential wastes, cleaning effluent screens/filters, and periodic tank pumping (e.g., every 3 to 7 years). Systems employing advanced treatment technologies and electromechanical components require more intensive O&M attention, e.g., checking switches and pumps, measuring and managing sludge levels (important for all systems), monitoring and adjusting treatment process and system timers, checking effluent filters, monitoring effluent quality, and maintaining disinfection equipment. Operators and service technicians should be trained and certified for the types of systems they will be servicing; services should be logged and reported into a management tracking system, such as EPA's TWIST (USEPA 2006), so that long-term performance can be tracked. The use of a dial-up modem or Internet-based monitoring equipment can improve operator efficiency and performance tracking when large numbers of systems are involved.

5.10 Residuals Management

Septic tanks contain settleable solids, fats, oils, grease, and other residuals that require periodic removal. The primary objective for septage management is to establish procedures for handling and dispersing the material in a manner that protects public health and water resources and complies with applicable laws. Approximately 67 percent of the estimated 12.4 billion gallons of septage produced annually in the United States is hauled to publicly owned treatment works or other facilities for treatment, while the remaining 33 percent is applied to land. Federal regulations (under Title 40 of the *Code of Federal Regulations* Part 503) and state/local codes strive to minimize exposure of humans, animals, and the environment to chemical contaminants and pathogens that are often present in septage. Residuals management programs should include tracking or manifest systems that identify sources, pumpers, transport equipment, final destination, and treatment or management techniques.

5.11 Training and Certification/Licensing

A variety of professionals and technicians including planners, regulators, designers, installers, operators, pumpers, and inspectors, are all involved in some aspect of a decentralized wastewater management program. Training, along with certification or registration, provides system owners and users with competent service providers and promotes professionalism among the industry. Service providers need to have a solid working knowledge of treatment processes, system components, performance options, O&M requirements, and laws/regulations. Universities, colleges, technical schools, agency-sponsored training programs, regional/local workshops, or formal/informal apprenticeship programs can provide such training. Service providers should have extensive and detailed knowledge of their own service areas and a general grasp of other related activities (e.g., planning or site evaluation). Service providers should pursue opportunities for cross-training, joint accreditation/certification, and sharing of training resources wherever possible.

5.12 Inspections and Monitoring

Perhaps the most significant shortcoming in existing management programs is the lack of regular inspections and performance monitoring. Area-wide monitoring regimes include testing groundwater and surface waters for indicators of substandard treatment, such as the presence of human fecal bacteria and excess nutrients. All systems need to be inspected, at an interval defined by the technological complexity of system components, the receiving environment, and the relative risk posed to public health and valued water resources. The best approach is to establish an inspection regime and schedule on the basis of the system's relative reliance on electromechanical components combined with health and environmental risk. Less effective surrogate approaches include, in order of descending effectiveness (1) requiring comprehensive inspections at regular intervals; (2) third-party inspections at the time of property transfer; (3) inspections only as part of complaint investigations.

5.13 Corrective Actions and Enforcement

A decentralized wastewater management program should be enforceable to assure compliance with laws and to protect public health and the environment. Management agencies should have the legal authority to adopt rules and assure compliance by levying fines, fees, assessments, or by requiring service providers to respond to system malfunctions. Program administrators should emphasize those tools that encourage compliance, rather than punishment. It also helps to have the support of the courts to implement an effective enforcement program. To assure compliance, management agencies typically need authority to do the following:

- Respond promptly to complaints
- Issue civil and criminal actions or injunctions
- Provide meaningful performance inspections
- Condemn systems or property
- Issue notices of violation (NOVs)
- Correct system malfunctions

- Implement consent orders and court orders
- Restrict real estate transactions
- Hold formal and informal hearings
- Issue fines and penalties

6 References

Anderson, D.L. 1998. Natural denitrification in ground water impacted by onsite wastewater treatment systems. In *Proceedings of the 8th National Symposium on Individual and Small Community Sewage Systems*, American Society of Agricultural and Biological Engineers, Orlando, Florida, March 8–10, 1998, pp. 336–345.

Bedessem, M.E. 2005. Nitrogen removal in laboratory model leachfields with organic-rich layers. *Journal of Environmental Quality* 34:936–942.

Behrends, L.L., L. Houke, P. Jansen, K. Rylant, and C. Shea. 2007. Recip Water Treatment System with U.V. Disinfection for Decentralized Wastewater Treatment: Part II: Water Quality Dynamics. In *Proceedings of the National Onsite Wastewater Recycling Association Annual Meeting*, Baltimore, MD, March, 2007.

Birgand, F. 2000. *Quantification and Modeling of In-stream Processes in Agricultural Canals of the Lower Coastal Plain*. North Carolina State University, Biological and Agricultural Engineering Department, Raleigh, NC.

Bushman, J.L. 1996. Transport and Transformations of Nitrogen Compounds in Effluent from Sand Filter-Septic System Draintile Fields. MS Thesis, Oregon State University.

Bussey, K.W., and D.A. Walter. 1996. *Spatial and temporal distribution of specific conductance, boron, and phosphorus in a sewage-contaminated aquifer near Ashumet Pond, Cape Cod, Massachusetts.* U.S. Geological Survey Open-File Report 96-472, 44 p.

Cheng, F., R. Muftikian, Q. Fernando, and N. Korte. 1997. Reduction of nitrate to ammonia by zero-valent iron. *Chemosphere* 35(11):2689–2695.

Cogger, C. 1988. On-site septic systems: The risk of groundwater contamination. *Journal of Envir. Health* 51(1):12–16. Sept/Oct, 1988.

Dimick, C.A., K.S. Lowe, R.L. Siegrist, and S.M. Van Cuyk. 2006. Effects of applied wastewater quality on soil treatment of effluent. In *Proceedings of the National Onsite Wastewater Recycling Association 15th Annual Conference*, Denver, CO, August 28–31, 2006.

Etnier, C.D., D. Braun, A. Grenier, A. Macrellis, R.J. Miles, and T.C. White. 2005. *Mico-Scale Evaluation of Phosphorus Management: Alternative Wastewater systems Evaluation.* Project No. WU-HT-03-22. Prepared for the National Decentralized Water Resources Capacity Development Project, Washington University, St. Louis, MO, by Stone Environmental, Inc., Montpelier, VT.

Gold, A.J., J.T. Sims, and G. Loomis. 2002. A risk-based approach to nitrogen contamination from decentralized wastewater treatment, In *Proceedings of Northeast Onsite Wastewater Treatment Short Course*, Newport, RI, March 24–26, 2002.

Heufelder, G., S. Rask, and C. Burt. 2007 *Performance of Innovative Alternative Onsite Septic Systems for the Removal of Nitrogen in Barnstable County, Massachusetts 1999–2007*. Barnstable County Department of Health and Environment, Barnstable, MA.

Higgins, J., G. Heufelder. S. Foss, J. Costa, and S. Corr. 2002. Advanced onsite wastewater treatment technology performance. In *Proceedings of Northeast Onsite Treatment Short Course*, Newport, RI, March, 2002.

Hiscock, K.M., J.W. Lloyd, and D.N. Lerner. 1991. Review of natural and artificial denitrification of groundwater. *Water Research* (GB) 25(9):1099–1111.

Integrated Upflow Services, Inc. 2010. *Information on Upflow Filter Denitrification Process.* <http://integratedwaterservices.com/denitrification/denitrification-upflow-filter-specifications/index.html>. Accessed April 28, 2010.

Jenssen, P.D., and R.L. Siegrist. 1990. Technology assessment of wastewater treatment by soil infiltration systems. *Water Science Technology* 22(3–4):83–92.

Joubert, L, P. Hickey, D.Q. Kellogg, and A.J. Gold. 2003. *Wastewater Planning Handbook: Mapping Onsite Treatment Needs, Pollution Risks, and Management Options.* NDWRCDP Report WU-HT-01-07,. Washington University, St. Louis, MO.

Lee, S., K. Lee, S. Rhee, and J. Park. 2007. Development of a new zero-valent iron zeolite material to reduce nitrate without ammonium release. *Journal of Environmental Engineering* 133(1):6–12.

Lombardo, P., N. Brown, J. Barnes, K. Foreman, and W. Robertson. 2005. Holistic approach for coastal watershed nitrogen management. In *Proceedings of the 2005 National Onsite Wastewater Recycling Association Annual Meeting* Conference Proceedings, Cleveland, OH, October, 2005.

Lombardo, P. 2006. *Phosphorus Geochemistry in Septic Tanks, Soil Absorption Systems, and Groundwater.* Lombardo Associates, Inc., Newton, MA.

Long, T. 1995. Methodology to predict nitrogen loading from on-site sewage treatment systems. In *Proceedings of the Northwest Onsite Wastewater Treatment Short Course,* ed, R.W. Seabloom. University of Washington, Department of Civil Engineering, Seattle, Washington, September, 1995.

Nitrabar. 2010. *A pan-European EC LIFE Environment Project to demonstrate a passive system for the removal of nitrates derived from agricultural practices*. <http://www.nitrabar.eu>. Accessed November 20, 2009.

Noah, M. 2006. Drainfield rehabilitation. *Small Flows Quarterly*. Winter 2006. West Virginia University, National Environmental Services Center, Morgantown, WV.

Omni Environmental Systems, Inc. 2010. *Information on OMNI denitrification process*. <http://www.omnirsf.com/design/omni_cycle.html>. Accessed November 29, 2009.

Otis, R.J. 2007. *Estimates of Nitrogen Loadings to Groundwater from Onsite Wastewater Treatment Systems in the Wakiva Study Area.* Prepared for Florida Department of Health, Tallahassee, FL. <http://www.doh.state.fl.us/environment/OSTDS/wekiva/task2/FinalReport_06-07.pdf>. Accessed August, 2009.

NSF International. 2009. *Final Evaluation Report, Pennsylvania Onlot Technology Verification Program, Orenco Systems, Inc. AdvanTex AX20N.* Prepared for Pennsylvania Department of Environmental Protection, by NSF International, Ann Arbor, MI.

Postma, F.B., A.J. Gold, and G.W. Loomis. 1992. Nutrient and microbial movement from seasonally used septic systems. *Journal of Environmental Health*. 55(2):5–10.

Rich, B. 2005. *La Pine National Demonstration Project Final Report, 1999–2005.* U.S. Environmental Protection Agency and supported by the Deschutes County, Oregon, Environmental Health Division, Oregon Department of Environmental Quality, and the U.S. Geological Survey.

Rich, B, D. Haldeman, T. Cleveland, J. Johnson, R. Weick, and R. Everett. 2003. Innovative systems in the La Pine National demonstration project. In *Proceedings of the Twelfth Northwest On-Site Wastewater Treatment Short-Course*, Seattle, WA, September, 2003.

Robertson, W.D., and J.A. Cherry. 1992. Hydrogeology of an unconfined sand aquifer and its effect on the behavior of nitrogen from a large-flux septic system. *Hydrogeology Journal* 1992:32–44.

Robertson, W.D., and J.A. Cherry. 1995. In situ denitrification of septic-system nitrate using reactive porous media barriers: field trials. *Ground Water* 33(1):99–111.

Smith, D.P., R.J. Otis, and M. Flint. 2008. *Florida Passive Nitrogen Removal Study*. Prepared for the Florida Department of Health, Tallahassee, FL.

Stacey, P.E. 2002. Nitrogen effects and management: Implementing the Long Island sound study. In *Proceedings of Northeast Onsite Wastewater Treatment Short Course*, Newport, RI, March 24–26, 2002.

Starr, R.C., and R.W. Gillham. 1989. *Controls on Denitrification in Shallow Unconfined Aquifers. In Contaminant Transport in Groundwater, Proceedings of the International Symposium on Contaminant Transport in Groundwater,* Stuttgart, Germany, April, 1989.

Stewart, L.W., and R.B. Reneau Jr. 1984. *Septic Tank Disposal Experiments using Nonconventional Systems in Selected Coastal Plain Soils*. Prepared for the Virginia Department of Health, Richmond, VA, and Virginia Polytechnic Institute and State University, Blacksburg VA.

Stewart, L.W., and R.B. Reneau Jr. 1988. Shallowly placed, low pressure distribution system to treat domestic wastewater in solils with fluctuating high water tables. *Journal of Environmental Quality* 17(3):499–504.

Stone Environmental. 2005. *Risk-Based Approach to Community Wastewater Management: Tisbury, Massachusetts*. Project No. WU-HT-00-26. Prepared for the National Decentralized Water Resources Capacity Development Project, Washington University, St. Louis, MO, by Stone Environmental, Inc., Montpelier, VT.

Tetra Tech. 2007. *Cost and Performance of Onsite and Clustered Wastewater Treatment Systems* (unpublished). Tetra Tech, Inc., Fairfax, VA.

Tyler, E.J., D.L. Mokma, and M. Corry. 2003. Soil hydraulic and treatment performance for onsite model performance code development. In *Proceedings of the Twelfth Northwest On-Site Wastewater Treatment Short Course*, Seattle, WA, September, 2003.

USEPA (U.S. Environmental Protection Agency) and NSF International. 2003. *Environmental Technology Verification Report for Bioclere.* EPA-832-F-02-025. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 1993. *Nitrogen Control*. EPA/625/R-93/010. U.S. Environmental Protection Agency, Offices of Research and Development and Water, Cincinnati, OH.

USEPA (U.S. Environmental Protection Agency). 1998. *Permeable Reactive Barrier Technologies for Contaminant Remediation*. U.S. Environmental Protection Agency, Office of Research and Development, Office of Solid Waste and Emergency Response, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 1999. *Water Efficiency Technology Fact Sheet—Composting Toilets*. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 2000. *Onsite Wastewater Treatment Systems Technology Fact Sheet 12—Land Treatment Systems*. EPA-625-R-00-008. U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 2002a. *Onsite Wastewater Treatment Systems Manual*. EPA-625-R-00-008. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 2002b. *Wastewater Technology Fact Sheet: The Living Machine*. EPA-832-F-02-025. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 2004. *Guidelines for Water Reuse*. EPA-625-R-04-108. U.S. Environmental Protection Agency, Washington, DC. <http://www.epa.gov/ord/NRMRL/pubs/625r04108/625r04108.htm>. Accessed April 27, 2010.

USEPA (U.S. Environmental Protection Agency). 2005. *Handbook for Managing Onsite and Clustered (Decentralized) Wastewater Treatment Systems*. EPA 832-B-05-001. U.S. Environmental Protection Agency, Office of Wastewater Management, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 2006. *The Wastewater Information System Tool (TWIST).* EPA 832-E-06-001. U.S. Environmental Protection Agency, Office of Wastewater Management, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 2007. *Wastewater Management Fact Sheet—Membrane Bioreactors*. U.S. Environmental Protection Agency, Office of Water, Washington, DC. <http://www.epa.gov/owm/mtb/etfs_membrane-bioreactors.pdf>. Accessed April 29, 2010.

USEPA (U.S. Environmental Protection Agency). 2009. *The Next Generation of Tools and Actions to Restore Water Quality in the Chesapeake Bay, A Revised Report Fulfilling Section 202a of Executive Order 13508.* U.S. Environmental Protection Agency, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 2010. *Individual and Clustered (Decentralized) Wastewater Management Program Elements.* Web Supplement. <http://www.epa.gov/owm/septic/pubs/onsite_handbook.pdf>. Updated January 2010. Accessed February 24, 2010.

Valiela, I., G. Collins, J. Kremer, K. Lajitha, M. Geist, B. Seely, J. Brawley, and C.H. Sham. 1997. Nitrogen loading from coastal watersheds to receiving estuaries: New method and application. *Ecol. Appl.* 7(2):358–380.

Vallino, J., and K. Foreman. 2008. *Effectiveness of Reactive Barriers for Reducing N-Loading to the Coastal Zone*, Submitted to The NOAA/UNH Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET). Ecosystems Center Marine Biological Laboratory, Woods Hole, MA.

Walker, W.G., J. Bouma, D.R. Keeney, and P.G. Olcott. 1973. Nitrogen transformations during subsurface disposal of septic tank effluent in sands: Ground water quality. *Journal of Environmental Quality* 2(4):475–480. Oct–Dec 1973.

Washington State Department of Health. 2005. *Nitrogen Reducing Technologies for Onsite Wastewater Treatment Systems*. Prepared for the Puget Sound Action Team, by Washington Department of Health, Olympia, WA. <http://www.psparchives.com/publications/our_work/hood_canal/hood_canal/n_reducing_technologies.pdf>. Accessed April 27, 2010.

WERF (Water Environment Research Foundation). 2006. *Decentralized Systems for Green Buildings and Sustainable Sites. WERF Stock No. DEC3R06.* December, 2006. <http://www.werf.org/AM/Template.cfm?Section=Home&CONTENTID=13376&TEMPLATE=/CM/ContentDisplay.cfm>. Accessed April 27, 2010.

WERF (Water Environment Research Foundation). 2010. *Distributed Water Infrastructure in Sustainable Communities: A Guide for Decision-makers.* WERF DEC3R06. March 2010. <http://www.werf.org/distributedwater>. Accessed April 27, 2010

WE&T Research Notes. 2009. Method shows promise for removing groundwater nitrate, researchers say. *Water, Environment, and Technology* 21(11):6–8.