Chapter 7

On-Site Drinking Water and Wastewater Treatment Technologies

CHAPTER 7

ON-SITE DRINKING WATER AND WASTEWATER TREATMENT TECHNOLOGIES

7.1 INTRODUCTION

A. **Purpose.** The purpose of this chapter is to identify on-site drinking water and wastewater treatment technologies which could be used to mitigate public health and environmental impacts from wastewater related issues within the Town of Eastham. In terms of wastewater treatment and recharge, this chapter will focus on the treatment technologies since the recharges (leaching facilities) are typically the same for each treatment technology and most property owners use traditional subsurface systems. This chapter will also review technologies and approaches that could be used for private drinking water supply and treatment for individual property owners.

On-site wastewater treatment and treated water recharge technologies are used in individual wastewater treatment systems. For the purpose of this report, cluster systems are considered an example of community/municipal systems and are discussed in Chapter 8. The on-site wastewater treatment technologies discussed in this chapter are identified here and then screened in Chapter 14 based on their ability to mitigate and prevent impacts to human health and/or the environment and to address existing problems within the Town. The ability of these technologies to consistently remove nitrogen from wastewater is an important factor and the advantages and disadvantages of these systems as they apply to Eastham are provided in this chapter. The on-site wastewater treatment technologies selected for further consideration will be included as part of the Town's Wastewater Management and Disposal Plan.

B. **Comparison of On-Site Wastewater Technologies with Community/Municipal Collection and Treatment.** The on-site wastewater technologies in this chapter are presented as an alternative to community (cluster)/municipal wastewater collection and treatment, which may involve the construction of a new wastewater treatment facility serving multiple properties. To properly evaluate on-site treatment system alternatives, it is important to understand some of the general advantages and disadvantages of the community/municipal collection and treatment systems, as summarized below.

Community/municipal collection and treatment has the following advantages:

- Wastewater can be removed from the area(s) of need, minimizing health threats and nitrogen loading to an area.
- Individual property owners will not have the responsibility of operating their own on-site wastewater treatment system.
- Fewer treatment and recharge sites will be required than for on-site systems.
- Large community/municipal wastewater treatment systems are reliable, provide high quality effluent, have professional operations staff, and have regular monitoring of the recharged water.
- An "economy of scale" to treat and recharge the wastewater at fewer/one location(s) can reduce capital and O&M costs.
- Fewer resources are required for the Town to operate/monitor fewer facilities.
- The ability to achieve TMDL limits is greatly improved because of the level of treatment provided by large community/municipal facilities.

Community/municipal collection and treatment has the following disadvantages:

- Sewer construction can potentially disrupt traffic and have a high capital cost associated with it (but sewers are also required for some on-site approaches).
- Treated water recharge issues, including siting, capacity, and impacts to sensitive coastal embayments can limit the amount of wastewater collected and treated and where it can be recharged.
- Community/municipal facilities may be located at great distances from the areas being served, increasing costs associated with wastewater collection and transfer.

7.2 INDIVIDUAL ON-SITE SYSTEMS – DRINKING WATER

A. **Introduction.** The on-site drinking water technologies in this chapter are presented as alternatives to town-wide public water supply. Based on the rural nature of the Town of Eastham, interest has been expressed in implementing point-of-use treatment technologies rather than a municipal drinking water supply system. A point-of-use technology is a technology that provides water treatment at the site where water for human consumption (drinking and cooking) is obtained. The likely spot for such a technology would be at a kitchen sink. A reverse osmosis filter would be the most applicable technology for this type of use. This section describes the reverse osmosis process along with its advantages and disadvantages. Although there are other point-of-use technologies that exist such as distillation or ion exchange, these are not evaluated in detail. If the Town were to consider reverse osmosis as a point-of-use process, a detailed evaluation of these other technologies is warranted. In addition, bottled water supply is identified as another on-site alternative, with its advantages and disadvantages.

1. **Reverse Osmosis**. Reverse osmosis is the process to remove suspended and dissolved solids from water with a semi-permeable membrane. Pressure is applied to the inlet side of the membrane which has a higher solids concentration, thereby forcing the water through the membrane; the membrane prevents the solids pollutant from passing through with the water.

The source water is supplied to the filter continuously; as pure water passes through the membrane, the solids are washed away by the incoming source water. The water that is rejected by the filter results in a significant amount of wastewater. Typical reverse osmosis filters require as much as 4 gallons of source water to produce one gallon of product water. The product water is stored until it is desired for consumption.

Water that has been filtered with reverse osmosis has very little buffering capacity and a low pH, and is chemically aggressive. Plastic or stainless steel piping is recommended for all plumbing that will come in contact with the filtered water.

Reverse osmosis systems have the following advantages:

- High removal rates (>90 percent) for nitrate.
- They produce a purified water.

The following are some of the disadvantages of reverse osmosis systems:

- Require new plumbing for parts in contact with product water.
- Require large areas, such as under sinks, for filter components and storage basins.
- Generates a high percentage of wastewater. Return water would be discharged back into the aquifer (which would add to aquifer degradation).

- Reliability and life of filter depends on influent water characteristics.
- Regulatory approval hurdles with respect to Town-wide installation.
- This option does not address other potential needs for a public drinking water supply system such as water flow to fight fires.

2. **Bottled Water.** Instead of producing product water with reverse osmosis, the other main on-site drinking water alternative would be to purchase bottled water, from either a store or from a home delivery service for drinking water purposes. According to the USEPA, bottled water is the fastest growing drink choice in the United States and Americans spend billions of dollars each year to buy it. For the purpose of this section, home water delivery is considered.

The following are some of the advantages of home water delivery:

- Service is set-up with regularly scheduled visits based on consumption.
- Water cooler is rented from the company providing water and thus is replaced upon operation failure.
- This on-site alternative is recognized by much of the public and is easily accepted.
- Minimal service costs for delivery.

The following are some of the disadvantages of home water delivery:

- As a drinking water option only, therefore care should be taken when using tap water for other activities such as cooking or bathing. Young children may accidentally drink bathroom tap water while bathing, brushing teeth, etc.
- This option does not address other potential needs for a public drinking water supply system such as water flow to fight fires.

7.3 INDIVIDUAL ON-SITE SYSTEMS - WASTEWATER

A. **Introduction.** Although community/municipal wastewater treatment technologies offer many advantages over individual on-site systems, there are many new developments/technology improvements with individual on-site systems that may prove feasible for the Town of Eastham. Also, there is much interest in individual on-site systems due to their required use by several local Boards of Health and the Alternative Septic System Test Center located at the Massachusetts Military Reservation.

The Town of Eastham has a long history of working with the Barnstable County Department of Health and Environment. Since 1999, I/A systems in Eastham have been studied and sampled by Barnstable County. The number of permitted I/A systems (as of April 2008) within the Town are noted below next to the technology with additional installation and sampling information as applicable.

On-site systems are used to treat wastewater from individual lots and may utilize one of several innovative and alternative (I/A) technologies. Wastewater flows less than 10,000 gpd are regulated by the Title 5 code, 310 CMR 15.000. Flows greater than 10,000 gpd require a state-issued groundwater discharge permit per 314 CMR 5.00. The following is the definition of I/A technologies in accordance with Title 5 Regulations (310 CMR 15.002):

> "Alternative Systems – Systems designed to provide or enhance on-site sewage disposal which either do not contain all of the components of an on-site disposal system constructed in accordance with 310 CMR 15.100 through 15.293 or which contain components in addition to those specified in 310 CMR 15.100 through 15.293 and which are proposed to the local approving authority and/or the Department for remedial, pilot, provisional, or general use approval pursuant to 310 CMR 15.280 through 15.289."

MassDEP has identified the allowable uses for each approved I/A system and has assigned each into one of four categories: remedial, pilot, provisional, and general use. Each of these categories is defined below.

> "The purpose of a **Piloting Approval** is to provide field testing and technical demonstration that an I/A technology can or can not function effectively under relevant physical and climatological conditions at one or more pilot facilities. Although information obtained during piloting is likely to be relevant to long term operation and maintenance concerns about a particular alternative system, approval for piloting is not intended, in and by itself, to provide a full evaluation of these issues.

Provisional Approval is intended to designate alternative systems that appear technically capable of providing levels of protection at least equivalent to those of standard on-site disposal systems and to determine whether, under actual field conditions in Massachusetts with broader usage than a controlled pilot setting, general use of the alternative system will provide such protection, and whether any additional conditions addressing long-term operation and maintenance and monitoring considerations are necessary to ensure that such protection will be provided.

Certification for **General Use** is intended to facilitate the use, under appropriate conditions, of alternative systems that have been demonstrated to provide levels of environmental protection at least equivalent to those of standard on-site systems.

The purpose of approval for **Remedial Use** is to allow for the rapid approval of an alternative system that is likely to improve existing conditions at a particular facility or facilities currently served by a failed, failing, or nonconforming system."

MassDEP has also identified I/A systems which are approved for general use and receive nitrogen reduction credits in nitrogen-sensitive areas. For the purposes of this evaluation, the various on-site treatment system technologies are grouped as follows:

1. **On-Site Systems.** Approved for general use (not credited for nitrogen removal) include:

   a. **Title 5 Septic Systems.**

   b. **JET Aerobic Wastewater Treatment.**

   c. **Orenco Intermittent Sand Filter.**

2. **Non-Discharge Systems.**

   a. **Tight tanks.**

b. **Waterless toilets.**
(Eastham = 2 permitted Clivus Composting Toilets)

c. **Urine source separation.**

3. **On-Site Nitrogen Removal Systems.** Also called I/A technologies, of which there are three types:

a. **Nitrogen Removal Systems**. Approved for **general use** by MassDEP in nitrogen-sensitive areas, which include:

- Recirculating sand filters that comply with Title 5
  (Eastham = 5 permitted recirculating sand filters; 3 installed)
- RUCK® systems (for flows less than 2,000 gpd)

b. **Nitrogen Removal Systems**. Approved for **provisional use** by MassDEP in nitrogen-sensitive areas, including:

- Bioclere (for less than 2,000 gpd)
  (Eastham = 13 permitted Bioclere Systems; 6 systems with 3 or more nitrogen samples)
- Bio-Microbics MicroFAST, High Strength FAST, and NitriFAST (for flows less than 2,000 mgd) and Smith & Loveless FAST, Modular FAST
  (Eastham = 51 permitted FAST Systems; 23 with nitrogen sample data)
- Waterloo Biofilter
  (Eastham = 8 permitted Waterloo Biofilter Systems with 3 being sampled)
- Amphidrome Process
  (1 permitted Amphidrome Process)
- Advantex
  (Eastham =16 permitted AvanTex®Systems; 4 installed)
- Nitrex™

c. **Nitrogen Removal Systems**. Approved for **piloting use** by MassDEP in nitrogen-sensitive areas, including:

- SeptiTech
  (Eastham = 23 permitted SeptiTech Systems; 6 systems with 3 or more nitrogen samples)
- Norweco Singulair
  (Eastham = 4 permitted Singulair Systems)
- RUCK CFT
- Cromaglass WWT System
- Omni Recirculating Sand Filter System
- Bio Barrier MBR WWT System
- Nitrex^{TM}–Plus

The technologies discussed in this chapter include the technologies that are approved for use by MassDEP at the time of this writing. The I/A systems are typically approved for five year time periods and, as a result, technologies may be added or removed from the list of approved technologies. This chapter is not intended to be an exhaustive list of all potential technologies that can be used but is a summary of the currently approved technologies.

B. **On-Site Systems Not Credited for Nitrogen Removal.**

1. **Title 5**. Title 5 systems consist of a septic tank, a distribution box, and a leaching area, as shown in Figure 7-1. Wastewater is discharged to the septic tank, as shown in Figure 7-2, where settleable solids sink to the bottom of the tank, and floatables (like grease and toilet paper) rise to the surface, forming a scum layer. Natural bacterial decomposition of organic matter occurs in the anaerobic conditions of the septic tank and produces ammonia. The liquid effluent is then discharged via the distribution box to a leaching area, where it percolates through stone bedding and the soil to receive additional treatment prior to reaching the groundwater. A typical leaching chamber and leaching trench are shown in Figures 7-3 and 7-4, respectively.

Septic tank effluent ammonia-nitrogen levels are generally in the range of 20 to 60 mg/L. Septic tank effluent concentrations of BOD and TSS are approximately 140 to 200 mg/L and 50 to 90 mg/L, respectively. In addition to pollutant removal in the septic tank, treatment in a Title 5 system occurs in the stone and soil interface through the action of a biological mat. Title 5 systems reduce bacterial contamination primarily via filtration of effluent through the mat and soils beneath the leaching area. If the leaching area is designed to promote aerobic conditions, nitrification can occur, converting the ammonia nitrogen (NH_3-N) to nitrate nitrogen (NO_3-N). Once the nitrogen is in the nitrate form, it can be converted to nitrogen gas and released to the atmosphere. Nitrogen removal rates can range from 10 to 40 percent, depending on the leaching area, system design, and loading. Nitrogen removal is not usually significant in a Title 5 system due to limited opportunities for denitrification (conversion of NO_3-N to N_2 [gas]) under typical aerobic conditions.

Soil characteristics are an important consideration for on-site systems, and many soils are not suitable for use as leaching areas. Those consisting of clay and silt (tight soils) do not percolate easily and may force the septic tank effluent to come to the surface, causing human health concerns, contaminated surface runoff, and possible shellfish bed closures.

The opposite condition can occur when the soils are sand or a sand/stone mix which percolates too fast. Fast soils generally have percolation rates of two minutes per inch or less, and allow the wastewater to travel through the soil with little additional treatment beyond that provided by settling in the septic tank.

Title 5 systems have the following advantages:

- Well proven, mechanically simple technology.
- No significant public acceptance concerns when they are properly sited and designed.
- Generally, no pumps are required for flows less than 2,000 gpd.
- Lower maintenance cost compared to I/A systems.

They have the following disadvantages:

- Septic tank requires pumping every two to three years (as do all individual on-site systems).
- The effluent from the system is of a comparatively low quality, and it is high in nitrogen. These systems do not provide advanced nitrogen removal. These systems are the highest sources of nitrogen and phosphorus to our estuaries and ponds as discussed in Chapter 4.

2. **JET Aerobic Treatment System**. This is an aerobic treatment system designed to achieve an effluent quality of 30 mg/L BOD and 30 mg/L TSS. Flow enters a primary settling chamber to remove solids, and then enters an aerated chamber where BOD and TSS removal is achieved. Aeration is provided by a mechanical aspirator that mixes the chamber and entrains air. The system uses both suspended growth and fixed-film bacteria to achieve the above stated removal levels.

Regular maintenance is required, as this is a mechanical system. Massachusetts requires that owners of this type of system follow a quarterly preventative maintenance schedule. A diagram of the JET Aerobic Treatment System is included in Figure 7-5.

JET systems have the following advantages:

- Produce relatively high quality effluent for BOD and TSS parameters.
- Allows for variances to reduce leaching area or separation to groundwater.
- Approved for General Use in Massachusetts (not in nitrogen-sensitive areas).

They have the following disadvantages:

- Higher capital cost and O&M costs than standard Title 5 systems.
- Requires routine maintenance, beyond the typical pumping of a septic tank.
- Currently only approved to handle flows up to 1,500 gpd.

3. **Orenco Systems Sand Filters.** Orenco Systems, Inc. manufactures an intermittent sand filter and a recirculating trickling filter, which can be installed either as a component of a new septic system or retrofitted into an existing septic tank. Intermittent sand filters are designed to disperse daily septic tank effluent flow over a distribution area throughout the course of a 24-hour period. The even distribution provides for a higher quality final effluent because it allows for more efficient use of the soil absorption system. In a recirculating trickling filter, the septic tank is fitted with a small trickling filter on top of the tank and a PVC pump vault inside the tank. The pump vault houses both a recirculation pump and an effluent pump. Inlet holes in the pump vault allow septic tank liquid to enter the vault, where it is either recirculated to the trickling filter or pumped to a leaching area. Nitrification occurs in the trickling filter, and with a recirculation ratio of 15 to 1, the effluent is denitrified after returning to the septic tank. A diagram of the Orenco intermittent sand and trickling filters is included in Figure 7-6.

Orenco filters have the following advantages:

- Better treatment than a Title 5 system can be attained and the leaching size can be reduced.
- Septage pumping requirements are similar to those of a standard septic system.
- Proven technology.
- Systems are approved for General Use in Massachusetts (not in nitrogen-sensitive areas).
- Can be retrofit into an existing system at a relatively low cost.
- No significant environmental or public acceptance concerns when they are properly sited and designed.
- The process operation is flexible, with the ability to adjust cycle times.

Orenco systems have the following disadvantages:

- Costs are typically higher than those of a standard septic system.
- Temperature sensitive in winter.
- More maintenance is required than a standard septic system due to mechanical and electrical components.

C. **Non-Discharge Systems.**

1. **Tight Tanks.** Tight tanks are non-discharge systems that collect and store the wastewater until it can be removed by a septage hauler. All of the wastewater generated by the household or business goes directly into the tight tank. The storage tank typically has a level indicator with an alarm, and a signal is transmitted when the liquid level reaches a specified height. When the tank is full, a septage hauler empties the tank and transports the contents to a treatment facility.

Tight tanks have the following advantages:

- Simple technology.
- No significant environmental concerns when they are properly sited and designed.

- Wastewater is not discharged to the ground; therefore groundwater mounding or nitrogen loading is not a concern.
- Require less land area than a septic system (no leaching area).
- Water use is often reduced because most water used must be transported and disposed off site at a high cost. Therefore the owners are conscious of their water use.

They have the following disadvantages:

- MassDEP does not consider tight tanks an adequate long-term solution.
- High operational costs due to frequent pumping and disposal.
- Potential for frequent pump-truck traffic and odors that occur during pumping.
- Wastewater treatment and disposal issues are transferred to another location.

2. **Waterless Toilets.** Water consumption, wastewater flow, and pollutant loading can be reduced using waterless toilets. Waterless toilet systems operate by separating black wastewater and gray wastewater. Black wastewater is toilet waste and gray wastewater is generated from all other or non-toilet sources, such as washing clothes and dishes, and bathtub and shower use. Black wastewater is treated in the waterless toilet unit, and gray wastewater is discharged to a septic system with potential size reductions. The two most common wastewater toilet systems are composting toilets and incinerating toilets.

Composting toilets recirculate the black wastewater over remaining solids to promote a natural decomposition process. Incinerating toilets burn black wastewater and generate a small quantity of ash and gas. Composted material and ash are periodically removed from the respective systems, and air filters and exhaust units are used to minimize odors. Public acceptance of waterless toilet systems is often low due to the composting, incinerating, and handling of human waste within living spaces. A potential use of waterless toilets is in public restrooms and convenience stations. This option eliminates the need for individual users to handle human waste, and would remove the composting process, odors, and incinerating process from residential areas. Diagrams of composting and incinerating toilets are included as Figures 7-7 and 7-8, respectively.

Waterless toilets have the following advantages:

- Wastewater flows and loads are reduced if properly designed and installed.
- Water consumption is reduced.
- Minimal environmental concerns occur when properly sited and designed.
- Composting toilets require minimal energy use.
- Size of standard septic system can be reduced to treat only gray wastewater.
- Routine maintenance is minimal and requires no special training.

Waterless toilets have the following disadvantages:

- Public acceptance is generally low.
- Incinerating toilets generally have high energy requirements.
- Handling of composting toilet contents can be objectionable.
- Incineration units are likely to generate odors if not vented properly or if multiple units are located in densely developed areas.
- Not well-suited to high seasonal peak loading.
- Retrofitting the plumbing to separate black and gray wastewater flows can be difficult and expensive.

3. **Urine Source Separation.** Water consumption and wastewater flow could be reduced using urine source separation technology. Urine separating toilet systems operate by separating urine from fecal material at toilet use. The idea behind the technology is that urine constitutes less than 1 percent of the wastewater volume, but contains most of the nutrients in wastewater. Approximately 80 percent of the nitrogen and 50 percent of the phosphorus in wastewater is derived from urine. Urine also contains most of the micro-pollutants in wastewater, such as pharmaceuticals and endocrine active compounds.

Urine source separation technology requires the use of specially designed toilets for the separate collection of urine. Urine is then stored separately in tanks, either located in the basement of the house or adjacent to the house. Public acceptance of urine separation technology would likely be low due to behavior modification of nearly half the population as proper use includes sitting on the toilet during every use.

Diagrams of how a urine source separation toilet operates as well as urine collection tank examples are included as Figure 7-9. Due to lack of municipal precedence and study, specifically in the United States, the following advantages and disadvantages are derived from a pilot study conducted in Switzerland.

Urine source separation toilets have the following advantages:

- Water consumption may be reduced with lower volumes of water required for flushing.
- Minimal environmental concerns occur when properly sited and designed.
- The nutrients in the urine could be positively recirculated in the environment by use as fertilizers after processing at an industrial facility.

Urine source separation toilets have the following disadvantages:

- Homeowner renovation costs would include new toilets, plumbing, and urine storage facilities. Urine separating toilets are likely to be costly and lack decorative design options which may decrease homeowner acceptance.
- Increased homeowner disposal hauling costs associated with two separate collection systems.
- Septage hauling trucks may need retrofitted equipment to properly handle concentrated urine.
- Technology works correctly with proper use. Proper use is limited to sitting on the toilet, meaning behavior modification for males or installation of a urinal.
- Technology works correctly with proper maintenance, which includes removing urine scale that can block pipes over time and using certain cleaning agents which would not contaminate the collection tank.
- Human urine use as an agricultural fertilizer may not be socially acceptable.
- Not well suited to high seasonal community and tourist population.
- No municipal precedence in the U.S. and the feasibility needs to be better demonstrated from regulatory, implementation, and cost aspects.
- Fertilizer use would have to be outside of a nitrogen sensitive area to aid in compliance with TMDLs.

D. **On-Site Systems Approved for General Use in Nitrogen-Sensitive Areas.**

1. **Recirculating Sand Filters (Non-Proprietary Filters).** Sand, rock, or mixed media recirculating filters are non-proprietary systems with a recirculation tank and filter. Septic tank effluent flows from the septic tank to the recirculation tank, where it is pumped to the top of the filter and over the media. A portion of the flow is recirculated back to the recirculation tank and the remaining flow is discharged to the leaching area. A diagram of a typical recirculating sand filter is shown in Figure 7-10.

Anaerobic decomposition occurs in the septic tank, changing organic matter to ammonia. The ammonia is then converted to nitrate in the aerobic filter media. The recirculated effluent then undergoes denitrification in the recirculation tank, and nitrates are converted to nitrogen gas. The nitrogen gas is then lost to the atmosphere, yielding a net loss of nitrogen from the wastewater. Many variations on the basic system are available to handle the specific needs of a project or site.

Maintenance includes periodic removal and replacement of the upper layers of media or backwashing and schedule pump maintenance. In emergencies, such as power loss, the system can be designed to function as a flow-through system, with treatment equivalent to a standard Title 5 system.

Recirculating sand, rock, or mixed media filters have the following advantages:

- Approved for General Use by MassDEP in nitrogen-sensitive areas.
- Septage pumping requirements are similar to those of a standard septic system.
- Well proven technology with operating history since the 1970s.
- Systems do not require a high level of technical skill to operate when designed and installed correctly.
- Better treatment than a standard Title 5 system can be attained and the leaching size can be reduced.
- No significant environmental or public acceptance concerns when they are properly sited and designed.
- The process has operational flexibility, with capability to adjust cycle times.
- Removal rates are approximately 50 percent for nitrogen, depending on the system.

They have the following disadvantages:

- More maintenance is required than for a standard septic system due to mechanical and electrical components.
- Generally requires a larger land area than a standard septic system. Land surface may be occupied by the filter unit and not available for other use.
- Systems are sensitive to temperature and must be protected from freezing.
- Costs are higher than those of a standard septic system.

2. **RUCK® System.** The traditional RUCK® system is designed to divide the black (toilet wastes) and gray (non-toilet wastes) wastewater and treat each in separate septic tanks. The two flows are typically piped separately from a home (or group of homes) and divided to either a black water or gray water septic tank. Black water flows through the RUCK® filter, which is constructed of sand or other media. The filter is where nitrification occurs. The effluent is then returned to an anaerobic tank and mixed with the gray water to promote denitrification, using the gray water as a carbon source. The gray wastewater septic tank effluent is discharged through a distribution box to a standard leaching area. These systems are used primarily for nitrogen removal. Figure 7-11 presents a diagram of the RUCK® system.

The RUCK® CFT is the commercial version of the residential RUCK® described above and is currently approved for Pilot Use in nitrogen-sensitive areas. RUCK® CFT systems are different than the traditional RUCK® systems because the CFT version requires energy, a part-time operator and the addition of a carbon source.

The traditional RUCK® system has the following advantages:

- Approved for General Use in nitrogen-sensitive areas (for flows less than 2,000 gpd).
- No significant environmental or public acceptance concerns when they are properly sited and designed.
- Low operational and maintenance costs.
- Nitrogen removal rates are approximately 50 percent, depending on the system and site.
- Routine maintenance requires no special training.

The traditional RUCK® system has the following disadvantages:

- Costs are typically higher than those of a standard septic system.
- Requires more space than a standard septic system.
- Requires more maintenance than a standard septic system due to mechanical and electrical components.
- Pumps and/or fans are used, which must be maintained and periodically replaced.
- Retrofitting the plumbing to separate black and gray wastewater flows can be difficult and expensive.

E. **On-Site Systems Approved for Provisional Use in Nitrogen-Sensitive Areas.** The remaining nitrogen removal systems (both Provisional and Piloting) can be considered recirculating treatment technologies. Recirculating treatment technologies are a category of I/A systems which are used in combination with standard septic systems. These systems typically include a recirculation chamber and a media to support microbial growth, which biologically treats the wastewater prior to discharge through a leaching system. A percentage of the wastewater is recirculated through the system, depending on influent quality, required effluent quality, and system design.

Recirculating treatment technologies vary in the type of media used, the wastewater pumping arrangement, and the overall system configuration. Some of these systems are produced by a specific manufacturer and are commonly referred to by their trade names. This section identifies and describes many of the recirculating treatment technologies and respective manufacturers that are currently approved for use in Massachusetts. The main disadvantage of these systems is the six- to eight-week startup period for biomass development. Summer residences are typically used over a three-month period; therefore, these systems do not provide the maximum performance during the first half of the period in which the residence is in use.

1. **Bioclere.** Bioclere is a trickling filter and pump unit together in one manufactured unit, designed to treat the anaerobic effluent from a septic tank, which is high in ammonia. The filter media is PVC or polypropylene. Effluent from the septic tank is pumped to a distributor, which spreads the wastewater over the top of the media, where aerobic conditions allow nitrification to occur (conversion of ammonia to nitrate). In the media, anaerobic micro-sites form where some limited denitrification (NO_3-N to N_2 [gas]) can take place. However, the majority of denitrification occurs when the effluent is collected at the base of the filter, and about

70 percent of the flow is recirculated back to the anaerobic septic tank. The rest of the effluent is discharged to a leaching area. A diagram of a Bioclere treatment unit is shown in Figure 7-12.

Installation of the Bioclere tank is relatively simple. One treatment unit contains a pump, a distributor, and the filter media. The treatment unit can either be retrofitted into existing septic systems by reusing the septic tank, piping, and leaching area, or it can be installed into new systems. The sealed double wall of the treatment unit provides insulation to minimize cold weather impacts. Nitrogen reductions of up to 50 percent are possible. The system can handle flow variations by varying the recirculation rates, and the units can handle increased flow by inserting additional media into the unit.

The Bioclere system has the following advantages:

- Well proven technology in Massachusetts.
- No significant environmental or public acceptance concerns when properly sited and designed.
- The process operation is flexible, with ability to adjust cycle times and add additional media.
- The basic system has relatively low operation and maintenance costs. The pump contained in the unit is easily accessible for replacement, when required.
- Septage pumping requirements are similar to those of a standard septic system.
- Better treatment can be attained and the leaching size can be reduced.
- Nitrogen removal rates are approximately 50 percent.

They have the following disadvantages:

- Costs are typically higher than those of a standard Title 5 system.
- Maintenance agreements are required and have an associated cost.
- More maintenance is required than a standard Title 5 system due to mechanical and electrical components (fans and pumps). Pumps typically require replacement.
- Generally require a larger area than a standard Title 5 system.
- Tops of Bioclere tanks are above ground.
- Provisional approvals typically allow for a limited number of installations.

2. **Micro-, High Strength-, Nitri-, and Modular-FAST.** The modular fixed activated sludge treatment (FAST) systems are constructed using a submerged filter unit installed below ground in a configuration similar to that of a standard septic tank. Wastewater enters the primary settling zone of the tank, where primary solids removal is achieved. Flow is then recirculated by means of a centrally located draft tube through the submerged FAST filter, which is located at the effluent end of the tank. A small portion of the recirculated wastewater flow is periodically discharged to a leaching area. An enclosed blower supplies air to the system in order to support bacterial growth on the filter media. Nitrification and denitrification are achieved as part of the FAST system design and result in an approximate total nitrogen removal rate of 50 percent. A diagram of the FAST system is included as Figure 7-13.

The FAST system has the following advantages:

- Proven technology in Massachusetts.
- Septage pumping requirements are similar to those of a standard septic system.
- The basic system uses a small mechanical aerator, which is accessible for service or replacement.
- No significant environmental or public acceptance concerns when they are properly sited and designed.
- Generally requires same land area as a standard septic system.

The FAST system has the following disadvantages:

- Costs are typically higher than those of a standard Title 5 system.
- More maintenance is required than a standard Title 5 system due to mechanical and electrical components.
- Pumps and blowers are used which must be maintained and periodically replaced; a backup power source is required.
- The blower can be relatively noisy in a quiet residential area and therefore must be enclosed.

3. **Waterloo Biofilter.** The Waterloo Biofilter consists of a 6-foot by 6-foot by 4-foot enclosure that includes filter media, an air ventilation system, and a wastewater distribution system. The distribution system pumps effluent from the septic tank and sprays it over the surface of the media. Wastewater trickles through the media while air is blown through the

system. The system uses a small ventilation fan and an effluent pump timed via a control panel to dose effluent at frequent intervals over a 24-hour period. The effluent is collected at the base of the biofilter and a portion is recirculated back through the media, while the rest is discharged to a leaching area. The mechanism for nitrogen removal is similar to the recirculating filters described earlier. A diagram of the Waterloo Biofilter is included as Figure 7-14.

The Waterloo Biofilter has the following advantages:

- Septage pumping requirements are similar to those of a standard septic system.
- No significant environmental or public acceptance concerns when they are properly sited and designed.
- The process operation is flexible, with the ability to adjust cycle times.
- The basic system uses a small pump, which has low O&M costs. The pump is easily accessible for service or replacement.
- Although the design hydraulic loading rate is 10 gal/ft^2/day, it can handle surges of up to 49 gal/ft^2/day for several days with little effect on effluent quality.
- Better treatment can be attained and the leaching size can be reduced.
- Removal rates for nitrogen are approximately 50 percent. Effluent BOD and TSS are expected to be <30 mg/L year. Fecal coliform removal is typically 99 percent.

They have the following disadvantages:

- Costs are typically higher than those of a standard septic system.
- Systems are sensitive to the temperature of the septic tank effluent entering the system. Insulation of the septic tank is recommended.
- More maintenance is required than a standard septic system due to mechanical and electrical components.
- Pumps and/or fans are used which must be maintained and periodically replaced.
- Denitrification unit periodically requires recharging with material like sawdust or leaves to serve as a carbon source for denitrification.
- Unit may need to be installed above-ground depending on depth to groundwater.

4. **Amphidrome Process.** The Amphidrome Process combines filter technology with a biofilter, an equalization tank, a clearwell, and the common components of a septic system. Wastewater flows by gravity from an equalization/septic (anoxic) tank through the biofilter into

a clearwell. Wastewater is then pumped in reverse through the biofilter to the anoxic tank. The biofilter alternates between aerobic and anoxic conditions, providing nitrification and denitrification as the cycle is repeated. Wastewater is allowed to cycle through the system several times before it is discharged. A diagram of the Amphidrome Process is included as Figure 7-15.

The Amphidrome Process has the following advantages:

- Utilizes deep bed filter technology, which has a reliable performance record.
- Septage pumping requirements are similar to those of a standard septic system.
- It has demonstrated very good nitrogen removal in several cluster and commercial installations on Cape Cod (greater than 50 percent nitrogen removals).

The Amphidrome Process has the following disadvantages:

- Costs are typically higher than those of a standard septic system.
- Pumping requirements are high due to internal treatment configuration. Nitrogen removal ability is sensitive to sludge accumulation.
- More maintenance is required than a standard septic system due to mechanical and electrical components.
- Pumps and/or fans are used, which must be maintained and periodically replaced.
- Startup time can be as long as 12 weeks, depending on ambient temperature, so it may not be suitable for seasonal homes.

5. **AdvanTex®.** The AdvanTex® system is a textile filter technology. The main components are a control panel, a filter pod, a recirculating splitter valve, a pumping package, and a processing tank. The filter material consists of an engineered textile that has greater surface area than sand or gravel, allowing greater volumes of wastewater treatment in less space. After initial settling in the first compartment of the processing tank, effluent is pumped to the filter pod. As effluent percolates through the filter media, a biological film develops, providing additional BOD, TSS, and nitrate removal.

The splitter valve directs a portion of the flow to the effluent discharge and a portion back to the processing tank. The splitter valve also maintains a minimum water level in the processing tank; therefore, all of the treated effluent is recycled back to the processing tank when there is no influent. Effluent discharge is controlled by a timer, which discharges in "microdoses." The microdoses occur for relatively short intervals, typically 72 times per day. A process diagram is shown in Figure 7-16.

AdvanTex® systems have the following advantages:

- The system can be installed within a small footprint.
- High quality effluent (5 mg/L BOD and TSS) can be used for drip irrigation.
- Septage pumping requirements are similar to those of a standard septic system.
- No significant environmental or public acceptance concerns when they are properly sited and designed.
- The process operation is flexible, with the ability to adjust cycle times.
- The basic system uses a small pump, which has low operational and maintenance costs.

AdvanTex® systems have the following disadvantages:

- Costs are typically higher than those of a standard septic system.
- More maintenance is required than a standard septic system due to mechanical and electrical components.
- Pumps and/or fans are used, which must be maintained and periodically replaced.
- May require media replacement at a higher cost than a system with sand or gravel media.

6. **NITREX™ System.** This system is a filter unit that can be added to the end of an I/A system. The system requires a nitrified effluent for the unit to work; therefore a treatment process beyond a normal septic system is required prior to this system. The filter media is contained in a tank and is a gravity flow-through system. The media is comprised of wood chips and cellulose. See Figure 7-17.

The NITREX™ system has the following advantages:

- Septage pumping requirements are similar to those of a standard septic system.
- No significant environmental or public acceptance concerns when they are properly sited and designed.

- Better treatment can be attained and the leaching size can be reduced.
- Does not require pumping.
- Excellent nitrogen removal is possible (greater than 50 percent) when the upstream treatment process has converted all the organic and ammonia nitrogen to nitrate nitrogen.

The NITREX™ system the following disadvantages:

- Costs are typically higher than those of a standard septic system.
- Requires a very effective nitrification process as an earlier treatment step to provide a nitrified effluent to the system.
- Media life is unknown and is expected to need replacement in 10 to 20 years.

F. **On-Site Systems Approved for Piloting Use in Nitrogen-Sensitive Areas.**

1. **SeptiTech System.** This system is a fixed-film-type system. The first two tanks or chambers of the system provide solids settling and the anoxic zone for denitrification. The second chamber contains trickling filter media and wastewater is recirculated within this chamber for treatment. Flow is also recirculated back to the anoxic zone to promote denitrification. A diagram of the SeptiTech system is included as Figure 7-18.

The SeptiTech system has the following advantages:

- Septage pumping requirements are similar to those of a standard septic system.
- No significant environmental or public acceptance concerns when they are properly sited and designed.
- Better treatment can be attained and the leaching size can be reduced.
- No supplemental carbon required.

It has the following disadvantages:

- Costs are typically higher than those of a standard septic system.
- More maintenance is required than a standard septic system due to mechanical and electrical components.
- Pumps are used which must be maintained and periodically replaced.

2. **Norweco Singulair.** This system (illustrated in Figure 7-19) is a type of extended aeration system. The treatment process is contained within a three-chambered tank. The first chamber provides solids settling; the second chamber is the aerobic zone where the wastewater is aerated to promote BOD removal and nitrification; and the third chamber is the final settling chamber. This chamber is equipped with a filtration unit to aid in clarification prior to effluent disposal. The system is followed by a recirculation chamber to pump 10 to 20 percent of the flow back to the first chamber for nitrogen recycle.

The Singulair system has the following advantages:

- Septage pumping requirements are similar to those of a standard septic system.
- No significant environmental or public acceptance concerns when they are properly sited and designed.
- Better treatment can be attained and the leaching size can be reduced.

They have the following disadvantages:

- Costs are typically higher than those of a standard septic system.
- More maintenance is required than a standard septic system due to mechanical and electrical components.
- Pumps are used which must be maintained and periodically replaced.

3. **Cromaglass System.** The Cromaglass system (illustrated in Figure 7-20) is a type of sequencing batch reactor treatment process. The system operates in five stages: fill, aeration, denitrification, settling, and discharge. Flow enters the first stage, where solids settle out and the remainder of the flow passes through a non-corrosive screen. After passing through the screen, the wastewater is aerated and mixed using submersible pumps. The pumps are then shut down to provide an anoxic condition to promote denitrification. Flow is then pumped to the clarifiers for final settling. Finally, flow is pumped from the clarifiers for effluent discharge to the leaching facilities.

The Cromaglass system has the following advantages:

- Septage pumping requirements are similar to those of a standard septic system.
- No significant environmental or public acceptance concerns when they are properly sited and designed.
- Better treatment can be attained and the leaching size can be reduced.

It has the following disadvantages:

- Costs are typically higher than those of a standard septic system.
- More maintenance is required than a standard septic system due to mechanical and electrical components.
- Pumps are used which must be maintained and periodically replaced.

4. **Omni Recirculating Sand Filter.** The Omni recirculating sand filter is a proprietary recirculating sand filter. The functioning and setup of the system is very similar to the process discussed for recirculating sand filter in general use (see Figure 7-10).

The Omni recirculating sand filter has the following advantages:

- Modular design allows for easy installation.
- Septage pumping requirements are similar to those of a standard septic system.
- Does not require a high level of technical skill to operate when designed and installed correctly.
- Better treatment can be attained and the leaching size can be reduced.
- No significant environmental or public acceptance concerns when they are properly sited and designed.
- The process has operational flexibility, with capability to adjust cycle times.

The following are some disadvantages of the Omni recirculating sand filter:

- More maintenance is required than for a standard septic system due to mechanical and electrical components.
- Land surface may be occupied by the filter unit and not available for other use.
- Systems are sensitive to temperature and must be protected from freezing.

- Costs are typically higher than those of a standard septic system.

5. **Bio Barrier MBR WWT System.** The Bio Barrier is a membrane bio-reactor (MBR) process and is illustrated in Figure 7-21. The septic tank contains settling, anoxic, and aeration zones. The membrane, contained in the aeration zone, consists of several flat sheets of a filter with micro pores. Large solids are removed in the settling zone, after which the effluent flows through the anoxic zone and into the aeration zone. Air is introduced into the aeration zone via a pump. A portion of the effluent is recirculated back to the anoxic zone where denitrification occurs. The permeate pump uses vacuum pressure to pull treated water through the membranes, leaving behind large organic and inorganic particles.

The Bio Barrier has the following advantages:

- Modular design allows for easy installation.
- Does not require a high level of technical skill to operate when designed and installed correctly.
- No significant environmental or public acceptance concerns when they are properly sited and designed.

The Bio Barrier has the following disadvantages:

- More maintenance is required than for a standard septic system due to mechanical and electrical components.
- Above ground components includes the aeration blower and the control panel.
- Costs are typically higher than those of a standard septic system.

6. **NITREX™ Plus.** This system is a variation on the NITREX™ filter discussed previously. The NITREX™ Plus (shown in Figure 7-22) consists of a layer of sand above the NITREX™ media. Effluent flows from the septic tank by gravity into perforated PVC distribution pipes at the top of the sand layer. Effluent flows down through the sand layer and into the NITREX™ media layer. At the bottom of the NITREX™ media layer are perforated PVC collection pipes. Effluent is collected in these pipes and flows to the soil absorption system.

The NITREX™ Plus has the following advantages:

- Modular design allows for easy installation.
- Does not require a high level of technical skill to operate when designed and installed correctly.
- No significant environmental or public acceptance concerns when they are properly sited and designed.
- Does not require pumping for process (although some installations may require pumps to convey effluent to the various components).

The NITREX™ Plus has the following disadvantages:

- Occupies a larger area than a standard septic system since the unit is installed in addition to the septic tank.
- Costs are typically higher than those of a standard septic system.
- Media life is unknown and is expected to need replacement in 10 to 20 years.

G. **Nitrogen Removal Performance for On-Site Nitrogen Removal Systems.** The manufacturers of these systems typically provide operational data that characterizes the nitrogen removal performance of their systems. The testing procedures for the data provided by the manufacturer are highly variable and these systems are very sensitive to the influent flow characteristics and therefore proper education of the homeowner/end user is necessary to maximize the performance of these units, including controlling what cleaners are used and what wastes are disposed of in the septic system.

Barnstable County (with several partner agencies) has created the Massachusetts Alternative Septic System Test Center at the Massachusetts Military Reservation to test these systems with standardized testing procedures. Data from these tests is available on the web at www.barnstablecountyhealth.org/AlternativeWebpage/index.htm. It is recognized that these systems are tested with a constant flow of wastewater which may not be representative of systems used at individual houses, especially those with seasonal use, which is common on Cape Cod.

Performance of these I/A systems for the removal of nitrogen was released in July 2007 by the Barnstable County Department of Health and Environment. The report includes published findings of their analysis of several years of operating data of nitrogen removal septic systems. The data was from 487 single-family installations and 70 multi-family installations. The main finding is that "when systems having four or more samples are considered, 69 percent of the 297 single-family systems and 60 percent of the 50 multi-family I/A systems have medians that meet a regulatory threshold discharge standard of 19 mg/L or less of total nitrogen." Data analysis was presented for several system types and brands. In general, the analysis indicates that these systems do not meet their expected regulatory discharge standard 30 to 40 percent of the time based on median statistics. A further generalization indicates these systems remove approximately 50 percent of the nitrogen if the influent nitrogen is approximately 40 mg/L total nitrogen and the effluent is approximately 20 mg/L total nitrogen.

Several newer technologies, such as the NITREX™ system, did not have sufficient long-term operational data to participate in this analysis. Long-term performance of the newer technologies at individual homes and multi-family installations will be evident and better understood in the next few years. As an aside, all of the above listed systems (except NITREX™) can have additional processes added to them (like NITREX™ or anoxic zones) to improve denitrification.