Chapter 8

Community/Municipal Drinking Water Supply and Wastewater Treatment Technologies

CHAPTER 8

COMMUNITY/MUNICIPAL DRINKING WATER SUPPLY AND WASTEWATER TREATMENT TECHNOLOGIES

8.1 INTRODUCTION

A. **Purpose**. The purpose of this chapter is to identify technologies that can be used by the Town of Eastham as part of one or more new wastewater treatment and discharge facilities to meet the environmental health needs. This chapter also discusses municipal drinking water supply for the Town of Eastham to meet the human health needs. Wastewater collection, treated water recharge, and identification of potential sites for water supply, and wastewater treatment and recharge facilities are discussed in Chapters 9, 10 and 11, respectively. Screening of all technologies for potential alternatives is discussed in Chapter 14, and recommended technologies will then be considered for further detailed evaluation as part of the development of the Wastewater Management and Disposal Study.

Drinking water supply and wastewater treatment technologies are divided into the following groups:

1. Municipal drinking water supply systems.
2. Small wastewater treatment facilities incorporating biological nitrogen removal.
3. Larger community/municipal wastewater treatment technologies.
4. Technologies to achieve less than 3 mg/L total nitrogen.
5. Technologies to remove endocrine disruptors.
6. Considerations on treatment for phosphorus removal.
7. Disinfection technologies.
8. Residuals management.

8.2 MUNICIPAL DRINKING WATER SUPPLY SYSTEM

A town-wide public drinking water supply system would service every parcel in the Town of Eastham. In addition to establishing the well supply area(s) (which are further discussed in Chapter 11), a distribution system and water storage facilities would need to be constructed.

There are many benefits of a municipal drinking water supply system. Advantages include the following:

- Rigorous quality control and supply well sites are protected by law.
- Hydrants for fire protection (which may lower insurance rates).
- Enhanced property values.
- Water during power outages.
- Municipal drinking water addresses public health concerns.

Disadvantages may include the following:

- New municipal infrastructure is costly, and the planning is extensive.

Preliminary discussions have also begun at the time this draft report is being developed between the Towns of Eastham and Orleans regarding water supply from Orleans. The two towns may develop an agreement to supplement Eastham's municipal drinking water system should voters eventually approve the project. At this time, costs have not been developed for this alternative.

8.3 SMALL (CLUSTER/COMMUNITY) WASTEWATER TREATMENT FACILITIES INCORPORATING BIOLOGICAL NITROGEN REMOVAL

Small wastewater treatment facilities incorporating biological nitrogen removal are typically designed to treat and discharge wastewater flows greater than 10,000 gpd and are typically of a size less than 500,000 gpd, however they can serve cluster and community developments with flows less than 10,000 gpd. These treatment systems serve many properties and require a wastewater collection system.

Small wastewater treatment facilities utilize biological nitrogen removal processes that are compact in size and more mechanized than individual, on-site-type systems. These facilities can produce a treated effluent that meets the Class I permitted standards of 30 mg/L BOD_5, 30 mg/L TSS, and 10 mg/L nitrate-N. When designed specifically for higher performance and properly operated, they can provide even better treatment than Class I standards. The following biological nitrogen removal processes are typically used in these systems and are described in this section: rotating biological contactors, sequencing batch reactors, Amphidrome system, membrane bio-reactors, fixed activated sludge treatment (FAST) systems and Bioclere.

A. **Regulatory Impacts and Treatment Standards.** Wastewater discharges greater than 10,000 gpd require a groundwater discharge permit under the Massachusetts Groundwater Discharge Permit Program and the Groundwater Quality Standards described in 314 CMR 5.00 and 6.00, respectively. These regulations were discussed in greater detail in Chapter 3. The Cape Cod Commission typically requires that new development and redevelopment provide wastewater treatment to meet a 5 mg/L nitrogen limit at the treatment and recharge facility site. *"Guidelines for the Construction, Operation, and Maintenance of Small Treatment Facilities with Land Disposal"* has been published by MassDEP specifically governing these types of treatment facilities. These guidelines provide detailed design criteria for treatment and discharge facilities.

B. **System Components for Small (Cluster/Community) Wastewater Treatment Facilities.** Several system components are common to all small wastewater treatment facilities. These components are required by MassDEP's design guidelines or are required as part of a well-equipped treatment facility that can be easily operated and maintained during its design life. The main components of a small wastewater treatment facility are presented in Figure 8-1 and described below.

1. **Primary Clarifiers.** Primary clarifiers are settling tanks that reduce the organic loading to the biological nitrogen removal process by removing settleable solids and floatable material. The raw wastewater flows through the clarifier (typically large septic tanks for small wastewater treatment facilities) and the solids settle to the bottom, where they are collected and removed for disposal. MassDEP's design guidelines require the installation of primary clarifiers on all small wastewater treatment facilities, though they are not generally used for sequencing batch reactor processes.

2. **Flow Equalization.** Flow equalization is required to provide steady and relatively consistent daily wastewater flows and associated loadings to a small wastewater treatment

facility. A flow equalization tank stores the variable flows that occur periodically during the day, and equalization pumps convey a relatively constant flow from the equalization tank to the biological treatment process.

3. **Biological Nitrogen Removal Process.** This process utilizes a large concentrated population of microorganisms to treat the wastewater. The microorganisms are mixed with (or brought into contact with) the wastewater in an aerobic environment and biodegradable waste is metabolized by the microorganisms to new cell mass and carbon dioxide. This first step is commonly called carbonaceous (or BOD) removal. The second step is nitrification, during which ammonia in the wastewater is converted to nitrate-nitrogen under aerobic conditions. Both the first and second steps occur concurrently under aerobic conditions. When nitrogen removal is incorporated with biological treatment, a third step is required, in which the amount of oxygen entering the process is limited and the microorganism environment becomes anoxic. The anoxic environment causes the microorganisms to obtain oxygen by converting the nitrate-nitrogen to nitrogen gas, which removes the nitrogen from the wastewater and releases it to the atmosphere. A carbon source such as methanol may need to be added to the process to support the conversion of nitrate-nitrogen to nitrogen gas. This third step is called "denitrification." Biological nitrogen removal processes are the focus of this chapter and these technologies/processes being considered are described in the next section.

4. **Secondary Clarifiers.** Secondary clarifiers are an integral component of the rotating biological contactors and fixed activated sludge treatment systems. These clarifiers are used to separate the biological solids (sludge) from the treated wastewater, and they operate similarly to the previously described primary clarifiers.

5. **Effluent Filtration.** This is typically required by MassDEP following the biological nitrogen removal process. This process filters the effluent to remove most remaining particulate matter. The facilities include sand or other media filters and the necessary pumps and reservoirs to periodically backwash the filters and pump the dirty backwash water back to the biological treatment process. Effluent filtration is provided in the Amphidrome and membrane bio-reactor processes as part of the standard design, but is not typically required as part of the fixed activated sludge treatment systems.

6. **Disinfection.** Disinfection may be required prior to recharging the treated water to the groundwater. Disinfection can be accomplished by adding small quantities of sodium

hypochlorite to the effluent or more commonly by exposing the effluent to ultraviolet light, which inactivates the bacteria in the effluent. Disinfection is not typically required when subsurface leaching systems or subsurface drip irrigation are used for recharge unless it occurs within the Zone II of a drinking water well. Disinfection may be required when sand infiltration beds (open to the atmosphere), well injection, spray irrigation, or recharge to a surface water body are used.

7. **Treated Water Recharge Facilities.** These facilities are required to recharge and distribute the treated water to the ground. Two methods are commonly used, including sand infiltration beds and subsurface leaching systems, these and other options are discussed in detail in Chapter 10.

8. **Support Structures.** An operations building is required to shelter process equipment, store supplies, and operate and maintain the various treatment processes.

9. **Collection Systems.** Like larger wastewater treatment facilities, a collection system is required to collect the wastewater from the various properties. Technologies associated with collection are discussed in Chapter 9.

C. **Biological Nitrogen Removal Processes.**

1. **General.** The focus of evaluating wastewater treatment technologies is on the biological process. Biological treatment processes are divided into two general classifications: suspended growth processes and attached film processes. Suspended growth processes use the concentrated microorganism population suspended in the wastewater via mechanical mixing or injection of compressed air. Carbonaceous removal, nitrification, and denitrification are accomplished in one or more tank compartments during the process, and the microorganisms are settled from the wastewater to be reused in the process or are processed for disposal.

Attached film processes utilize a concentrated microbial population that adheres to a supporting media. The wastewater is circulated through tank compartments that contain the microorganism-coated media. At the end of the process, the wastewater is typically settled or filtered to remove any microorganisms that have sloughed from the media.

2. **Rotating Biological Contactors.** Rotating biological contactors are an attached growth process that utilizes disc-shaped plastic media mounted to a rotating shaft. The plastic media is partially submerged in a tank and provides a growing surface for microorganisms. The rotating shaft brings the microorganisms in contact with both the organic matter in the wastewater and oxygen in the atmosphere. As a result, aerobic bacteria metabolize solids and nutrients in the wastewater. Additional microorganisms are produced and removed from the treated effluent in a settling tank.

When rotating biological contactors are used for nitrogen removal, often an anoxic rotating biological contactor will follow the partially submerged (aerobic) rotating biological contactor to provide denitrification. The anoxic rotating biological contactor is completely submerged and is not aerated, thereby maintaining anoxic conditions. Methanol may be added to the anoxic rotating biological contactor to assist nitrogen removal. Both the aerobic and anoxic rotating biological contactors produce sludge that must be settled and removed from the effluent by means of secondary clarifiers. Rotating biological contactors may also be followed by denitrification filters or other processes to achieve these same limits. A process diagram of a rotating biological contactor is included as Figure 8-2.

Rotating biological contactors have the following advantages:

- The technology is used extensively for small treatment facilities and is well accepted by MassDEP.
- Energy requirements are low.
- Operational requirements are low.
- Can reliably achieve less than 10 mg/L total nitrogen.

They have the following disadvantages:

- Must be preceded by primary treatment.
- Capital costs are high.
- Cold weather performance is a concern and the tanks must be covered or enclosed in a building
- There is minimal process control.
- Generally require a larger land area than the other processes discussed in this section.

3. **Sequencing Batch Reactors.** Sequencing batch reactors are batch-type treatment processes. Aeration, anoxic reaction (for nitrogen removal), and settling are accomplished in a single basin, though parallel treatment paths are provided. The phases of the sequencing batch reactor process include fill, react, settle, draw, and idle. Wastewater is added during the fill cycle. During the react phase, BOD removal, nitrification, and denitrification reactions are completed by alternating the aeration cycle. The next phase is settling, followed by decanting of clarified effluent in the draw phase. Sludge is collected and removed during the idle phase. A process diagram of a sequencing batch reactor is included as Figure 8-3.

Nitrogen removal with sequencing batch reactors can be enhanced by modifying the length of the cycle times and monitoring the reactor contents to achieve the desired degree of treatment.

Sequencing batch reactors have the following advantages:

- Batch operation allows reactor contents to be retained until desired effluent quality is achieved.
- Return sludge pumping and internal recycle equipment associated with nitrogen removal are not required.
- Settling occurs under totally quiescent conditions with no influent flow.
- All biological treatment phases are provided in a single basin, reducing the need for additional tanks.
- Highly flexible operation with ability to adjust cycle times.
- The technology is now well accepted and used extensively.

They have the following disadvantages:

- A sophisticated control system with valves, timers, probes, and level sensors is required to control intermittent feeding, cycle times, phases, and process performance.
- The reactor volume is increased to allow for cycle times and use of the basin for settling.

4. **Amphidrome.** The Amphidrome process is a fixed-film, sequencing batch-type process designed for nitrogen removal. It combines filter technology with a biofilter, an anoxic/equalization tank, and a clearwell. Wastewater flows by gravity from the

anoxic/equalization tank through the biofilter and into a clearwell. Wastewater is then pumped in reverse through the biofilter to the equalization tank. The Amphidrome biofilter alternates between aerobic and anoxic treatment as the cycle is repeated. Wastewater cycles through the system before it is discharged. A diagram of an Amphidrome system is included as Figure 8-4.

The Amphidrome process has the following advantages:

- Tanks are typically below ground; therefore, visual impacts are minimal.
- Allows secondary treatment and nitrogen removal in a single reactor.
- Potential for air emissions is minimal, as filters are enclosed and below ground.
- The process provides physical filtering as well as biological nitrogen removal.

The Amphidrome process has the following disadvantages:

- Performance to date of these systems has been variable.
- Large headloss and below-grade installation requires effluent pumping.
- With tanks below grade, process control and access is limited.

5. **Membrane Bio-Reactor.** The membrane bio-reactor treatment system is an activated sludge process (Modified Ludzack-Ettinger process) packaged reactor tank that may be divided into multiple chambers. Wastewater flows first to an anoxic zone where nitrogen removal takes place. The mixture then flows to two aerobic zones, where organic material is metabolized and the treated effluent is separated from the mixture using a polymer membrane ultrafiltration system. The filter material is capable of isolating organic matter, bacteria, and viruses from the effluent flow. These pollutants are retained in the biological process tanks and are recycled back to the anoxic zone. Treated effluent passing through the filter membrane (permeate) is well filtered and can be used as non-potable water for toilet flushing or irrigation. The membrane bio-reactor process does not require any additions or modifications for nitrogen removal. Membrane bio-reactors are also available in package units however they are more commonly used with tertiary treatment. A diagram of the membrane bio-reactor tank is included as Figure 8-5.

The membrane bio-reactor process has the following advantages:

- Operator requirements are minimal due to fully automated process.
- Effluent can be reused for non-potable uses (e.g., toilet flushing or irrigation).

Membrane bio-reactor processes have the following disadvantages:

- Capital costs are high.
- Membrane replacement costs are high.
- Few installations in Massachusetts to verify performance.

6. **MicroFAST, High Strength FAST, NitriFAST and Modular FAST Systems.** There are various sizes and models available for the FAST systems manufactured by Bio-Microbics, Inc.; the MicroFAST, High Strength FAST, NitriFAST, and the Modular FAST developed by Smith & Loveless. All systems are fixed-film, aerobic processes that can be modified for nitrogen removal. All four FAST systems are designed for flows from 2,000 gpd to less than 10,000 gpd. Wastewater flows from the primary treatment process through the FAST media and is recirculated through a distribution system. A small portion of the recirculated wastewater flows through a clarifier and is periodically discharged to a leaching area. The modular FAST system can be designed with additional septic tanks to achieve necessary anoxic and reaeration zones and its modular setup allows the system to be designed around the owner's needs. Blowers supply air to the system to support bacterial growth on the filter media. A diagram of a FAST system is shown on Figure 8-6.

The FAST system has the following advantages:

- Relatively low area requirements.
- Proven effectiveness for nitrogen removal as well as secondary treatment.
- Approved for general use in Massachusetts and for provisional use in nitrogen-sensitive areas.
- FAST systems comprise the majority of treatment systems installed in Barnstable County.

They have the following disadvantages:

- Requires skilled operation.
- Higher energy costs for aeration.
- High process control requirements to optimize performance.

7. **Bioclere.** Bioclere is a trickling filter and clarifier in one manufactured unit that is 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. Aerobic conditions in the media allow nitrification to occur, converting ammonia to nitrate. In the media, anaerobic micro-sites may also 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 recollected 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. Bioclere systems treating flows greater than 10,000 gpd often incorporate denitrification filters or a dedicated anoxic zone for nitrogen removal. A diagram of a Bioclere treatment unit is shown in Figure 8-7.

Installation of the Bioclere is relatively simple. One treatment unit contains a pump, a distributor, and filter media. The sealed double wall of the treatment unit provides insulation to minimize cold weather impacts. The Bioclere can be used year-round or seasonally. However, it takes approximately six weeks for the microbial layer (biomass) to be established on the filter media before full treatment is achieved. Nitrogen reductions of 70 to 85 percent have been achieved. 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 and second most common unit in Barnstable County.
- No significant environmental or public acceptance concerns when the system is properly sited and designed.
- The process operation is flexible, with ability to adjust cycle times and to add additional media.

- The basic system has low operation and maintenance costs. The pump contained in the unit is easily accessible for replacement, when required.

The Bioclere system has the following disadvantages:

- The Bioclere units extend above the ground and may require additional vegetative landscaping to reduce aesthetic impacts.
- Pumps and/or fans are used which must be maintained and periodically replaced.
- Influent characteristics can have a significant impact on nitrogen removal performance.
- Operation intensive process.

D. **Residual Treatment and Disposal for Small (Cluster/Community) Treatment Facilities.** Residuals are byproducts of the wastewater treatment processes and include primary and secondary sludge, screenings, and grit. Primary sludge is produced in the primary clarifiers and is composed of the easily settled solids that enter the clarifier in the raw wastewater. Secondary sludge is collected and removed from the secondary clarifiers and consists of a concentrated population of microorganisms produced by the biological treatment process. Screenings are the large pieces of solid waste (rags, plastic articles, etc.) typically removed from the raw wastewater by a bar screen located at the head of the wastewater treatment facility or a primary clarifier. Grit is sand and other dense particles that are removed at the head end of the wastewater treatment facility, typically via an aerated grit chamber or grit separator.

Small wastewater treatment facilities often do not have primary clarifiers or grit removal facilities, and material that would be removed as primary sludge or grit is incorporated into the secondary sludge. In addition, small wastewater treatment facilities do not usually have sludge treatment or disposal facilities. Liquid sludge is usually transported off-site for treatment and disposal at a larger facility. The Tri-Town Septage Treatment Facility in Orleans would be the probable destination for the sludge produced by a new small wastewater treatment facility, or the sludge could be shipped directly to a regional disposal facility such as the Upper Blackstone Water Pollution Control Facility. A small quantity of screenings could be produced at a small wastewater treatment facility, and these screenings would be expected to be disposed of as a special waste in a regional landfill.

8.4 LARGER COMMUNITY/MUNICIPAL WASTEWATER TREATMENT TECHNOLOGIES

A. **Introduction.** Community/municipal wastewater treatment processes like the smaller wastewater treatment facilities include several typical system components: preliminary treatment, primary treatment, flow equalization, secondary/advanced treatment alternatives, and effluent polishing. These system components are described in the following sections; and, because the focus of this section is on the biological processes, each secondary/advanced treatment alternative is described in detail.

B. **Preliminary Treatment.** Preliminary treatment is designed to remove large and abrasive objects and solids from wastewater and is usually the first process of a centralized treatment facility. The removal of these objects prevents damage to treatment equipment such as pumps, valves, and pipelines.

Bar screens are used to remove large objects at the beginning of the wastewater treatment process, and the material removed is referred to as screenings. Preliminary treatment may include grit removal facilities to remove sand and other abrasive materials from the wastewater to prevent excessive wear on moving equipment and minimize heavy deposits in pipelines and channels. Grit removal equipment consists of tanks that allow grit and heavy solids to settle as wastewater flows through the tank. Aeration is used to keep organic materials in suspension to be treated in subsequent treatment processes.

C. **Primary Treatment.** Primary treatment is a process to remove settleable solids from the wastewater flow. The solids are removed by gravity settling and can be collected using mechanical equipment or by pumping. Primary treatment methods include primary clarification and primary treatment in large septic tanks.

Primary clarification typically utilizes large circular or rectangular tanks with mechanical equipment for collection and removal of solids and scum. As wastewater flows through the tank, solids settle to the bottom of the tank and the scum floats to the top of the tank; both are then collected and removed by mechanical equipment.

D. **Flow Equalization.** Flow equalization is used to even out the flow fluctuations at a treatment facility. Most municipal wastewater is produced during two to three hours in the morning and evening when water usage is highest. Flow equalization utilizes one or more storage tanks to store the wastewater during the hourly peaks and feed it evenly into the treatment process throughout the day.

E. **Secondary/Advanced Treatment Concepts and Configurations.** Secondary treatment processes are designed to remove solids from wastewater, reducing the BOD and TSS concentrations. Advanced treatment processes typically remove nutrients such as nitrogen and phosphorus. The most common and least expensive secondary and advanced treatment processes are biological processes.

Biological treatment of wastewater utilizes microorganisms to transform solids and organic matter into biological cell mass, carbon dioxide, and/or nitrogen gas. Biological processes provide an environment for microbial growth using nutrients, BOD, and TSS in the wastewater as a food source. Microorganisms are removed from the wastewater as settled sludge; carbon dioxide and nitrogen gas are released to the atmosphere.

Biological processes are classified as aerobic, anoxic, or anaerobic processes. Aerobic processes are those which occur only in the presence of oxygen; anoxic processes occur when there is minimal oxygen but sufficient nitrate nitrogen to act as an oxygen source; and anaerobic processes occur when there is no oxygen or nitrate present.

Biological processes are also classified by the physical configuration used for promoting microbial growth. The following sections provide a brief description of the four major types of biological processes:

1. **Attached Growth Processes.** Attached growth processes utilize an inert medium of plastic, stone, sand, or other material on which the microorganisms grow and multiply. The wastewater is brought in contact with the microorganisms (also called biomass) on the media, and the biomass consumes the solids and organic material to produce more biomass. Attached growth processes (also known as fixed-film processes) include trickling filters, rotating biological contactors, aerated biological filters, packed beds, and fluidized beds. These process names identify the configuration of the support media.

2. **Suspended Growth Processes.** Suspended growth processes are biological processes which maintain a concentrated supply of microorganisms suspended in the wastewater. The supply of microorganisms and organic solids are collectively referred to as mixed liquor suspended solids. Decomposition of solids and organic matter is achieved by combining untreated wastewater and mixed liquor suspended solids in a contact tank. The microorganisms grow and consume the solids and organic material. The microorganisms multiply and are later separated from the treated water to be reused in the process. Excess biological growth is wasted as sludge.

3. **Natural Treatment Systems.** Natural treatment systems are considered emerging technologies and have not been widely applied for nitrogen removal. They are not as well defined in terms of predictable performance and design criteria as are more conventional systems, and most have large land area requirements. These systems are generally regarded as experimental technology and may require pilot testing. Natural treatment systems include hydroponic systems such as solar aquatics and constructed wetlands. These systems rely on naturally occurring plants, aquatic life, and sunlight to remove contaminants.

4. **Nitrogen Removal Processes.** Nitrogen removal from wastewater is an established technology, but it requires larger process tanks and skilled operation. Nitrogen removal includes the two steps of nitrification and denitrification. Nitrification converts ammonia-nitrogen to nitrate-nitrogen, and denitrification converts nitrate-nitrogen into nitrogen gas, which is released to the atmosphere. Several nitrogen removal technologies are available and are identified in the following sections.

5. **Nitrogen Removal Performance Considerations.** As discussed previously in this chapter, biological nitrogen removal processes have typically been designed to meet the drinking water standard of 10 mg/L total nitrogen. As a result (when they are operated well), they will produce a treated water with an average total nitrogen concentration of 5 to 7 mg/L.

The coastal estuaries in Eastham and other Towns on Cape Cod are much more sensitive to nitrogen than drinking water supplies used for human consumption. Nitrogen concentration above the range of 0.3 to 0.7 mg/L (as identified by MEP) will cause water quality impacts. This value is significantly lower than the drinking water standard of 10 mg/L. As a result, greater nitrogen removal is required to meet environmental health thresholds as compared to the human health threshold.

Enhanced nitrogen removal systems are biological nitrogen removal systems designed with additional components to consistently produce a treated water of 3 mg/L total nitrogen on average. This performance level is considered by the regulatory agencies as the limit of best available wastewater technology for nitrogen removal, and this level of performance may be required to address the nitrogen and phosphorus limits needs in parts of Eastham.

Due to the regulatory nature of the nitrogen TMDLs, nitrogen removal performance may need to be lower than 3 mg/L for parts of Eastham if the recharge is located within watersheds with high nitrogen sensitivity. There are drinking water and industrial technologies that can be used to treat to lower levels even though they are not typically used for municipal wastewater treatment. Several of these technologies to attain less than 3 mg/L are also considered in this chapter.

F. **Secondary/Advanced Treatment Processes.** The following is a summary of biological and advanced processes that can be used for treatment of centralized wastewater flows. Some of the following technologies have been discussed previously in this chapter, so only the advantages and disadvantages are discussed again as they may differ from smaller facilities.

1. **Activated Sludge with Modified Ludzack-Ettinger (MLE) Process.** The activated sludge process is a suspended growth biological treatment process that utilizes a high concentration of microorganisms suspended in the wastewater flow. An aerobic environment is maintained in the reactor tank through either diffused or mechanical aeration. In addition to supplying oxygen, aeration provides mixing of the suspended solids and microorganisms. The mixture of wastewater and microorganisms passes from the reactor tank to a settling tank (clarifier) where the microorganisms are settled from the treated effluent. The settled microorganisms are then recycled and combined with influent wastewater to the Modified Ludzack-Ettinger process. Portions of the settled microorganisms are periodically removed as waste sludge.

Activated sludge processes can be modified to increase nitrogen removal by creating anoxic zones in the reactor tank that force microorganisms to use nitrate-nitrogen as an oxygen source and remove the nitrogen as nitrogen gas, which is released to the atmosphere. The Modified Ludzack-Ettinger process is an established process for removing nitrogen to the 5 to 10 mg/L total nitrogen range. A diagram of an activated sludge/Modified Ludzack-Ettinger process is included as Figure 8-8.

Activated sludge/Modified Ludzack-Ettinger processes have the following advantages:

- Relatively low space requirements compared to extended air type processes.
- Relatively low capital and O&M costs.
- No primary treatment requirements.
- Highly effective for nitrogen removal as well as secondary treatment.
- Provides flexibility in operation and process control.
- Easily expanded to handle high seasonal flows.

They have the following disadvantages:

- Require final settling tanks.
- Requires moderately skilled operation.

2. **Rotating Biological Contactors.** Rotating biological contactors are a fixed-film-type system that functions as described in Section 8.4. When considering only rotating biological contactors for nitrogen removal, a separate submerged (anoxic) rotating biological contactor follows the partially submerged (aerobic) rotating biological contactor to provide denitrification and remove nitrogen to the 6 to 10 mg/L total nitrogen range. Methanol (or a supplemental carbon source) must be added to the anoxic rotating biological contactor to assist nitrogen removal.

Rotating biological contactors have the following advantages:

- The technology is used extensively and is well accepted by MassDEP.
- Energy requirements are low.
- Operational requirements are low.

They have the following disadvantages:

- Must be preceded by primary treatment.
- Must be followed by a final settling tank.
- Capital costs are high.
- Cold weather performance is a concern and the tanks must be covered.
- There is minimal process control and flexibility for high seasonal flows.

- High space requirements compared to sequencing batch reactors and Modified Ludzack-Ettinger processes.

3. **Sequencing Batch Reactors.** Sequencing batch reactors are a suspended growth batch-type process that functions as described in Section 8.4. Nitrogen removal with sequencing batch reactors can be enhanced by modifying the length of the cycle times, monitoring the reactor contents to achieve the desired degree of treatment, and adding methanol. Sequencing batch reactors can remove nitrogen to the 5 to 10 mg/L total nitrogen range.

Sequencing batch reactors have the following advantages:

- Batch operation allows reactor contents to be retained until desired effluent quality is achieved.
- Settling occurs under totally quiescent conditions with no influent flow.
- All biological treatment phases are provided in a single basin, reducing the need for additional tanks, such as final settling tanks.
- Highly flexible operation with ability to adjust cycle times.
- Capital costs are relatively low.

They have the following disadvantages:

- A sophisticated control system with valves, timers, probes, and level sensors is required to control intermittent feeding, cycle times, phases, and process performance.
- Operations are more complex and require more skilled operators.

4. **Membrane Bio-Reactor.** The membrane bio-reactor treatment system is an activated sludge package process (Modified Ludzack-Ettinger process) as discussed in Section 8.5. Treated effluent passing through the filter membrane (permeate) can be used as non-potable water for toilet flushing or irrigation because it is well filtered. The membrane bio-reactor process does not require any additions or modifications for nitrogen removal, and the process can remove nitrogen to the 5 to 10 mg/L range.

The membrane bio-reactor process has the following advantages:

- No final settling tanks are required.
- Effluent can be reused for non-potable uses such as toilet flushing or irrigation.

Membrane bio-reactor processes have the following disadvantages:

- Capital costs are high.
- Membrane replacement costs are high.
- Few large installations to verify performance.

5. **Oxidation Ditches.** Figure 8-9 presents a process schematic for a typical oxidation ditch. Oxidation ditches were developed to minimize operational requirements and maintenance. Oxidation ditches are large tanks with long retention time with one or more fixed aerators located at strategic points to provide aeration and mixing as well as propulsion of flow around the tank. Wastewater flows in a continuous, circular (or oval) path around the ditch to act as a plug flow reactor. Ditches are designed to provide extended aeration with no primary settling tank. Since aeration is provided at key points in the loop, aerobic conditions are created downstream of the aerator, while anoxic conditions generally exist upstream of the aerator. Consequently, nitrogen removal is achieved.

Various systems have been developed or adapted for increased nitrogen removal to take advantage of this inherent characteristic of oxidation ditches. These processes typically utilize pre-anoxic and post-anoxic tanks to promote nitrogen removal and can remove nitrogen to the range of 5 to 10 mg/L total nitrogen. Oxidation ditches can be modified by adding tanks to form the Bardenpho process (this process uses a post-anoxic tank), which is capable of removing nitrogen to an effluent concentration of 3 mg/L on average. Oxidation ditches require more land area due to their relatively large volume requirements.

Oxidation ditches have the following advantages:

- It is an expensive but simple process with few mechanized systems.
- Requires minimal operator attention.
- Can achieve high level of nitrogen removal.
- Operation and maintenance costs are typically low.

They have the following disadvantages:

- Larger land area is required for new tanks as compared to all other systems.
- Typically higher capital costs for the large new tanks.
- Require secondary clarifiers.

6. **Aerated Biological Filters.** Aerated biological filters consist of submerged filter media that allows biological growth in the media. The filters act as deep upflow beds with air injected either below the bed or at an intermediate point, depending on the treatment process. They are used mainly for BOD and TSS removal and nitrification of ammonia. A denitrifying filter would typically follow aerated biological filters for nitrogen removal. A primary clarifier is typically required as a pretreatment step before the flow goes to the aerated biological filters. Figure 8-10 is a diagram of an aerated biological filter system.

Aerated biological filters have the following advantages:

- Reliable technology for BOD and TSS removal and some nitrogen removal.
- Potential for air emissions is minimal, as filters are enclosed in a building.
- Relatively small footprint.

They have the following disadvantages:

- High capital costs for primary treatment and the aerated biological filter.
- Cold effluent wastewater temperatures may impact the nitrification process.
- Requires denitrification filters to achieve total nitrogen limits less than 10 mg/L.

7. **Denitrification Filters.** Denitrifying filters follow the nitrification phase to provide separate-stage denitrification. A high level of nitrification would be necessary prior to the filters to achieve a low-level total nitrogen effluent because denitrification filters can only denitrify effluent that has already been nitrified. Denitrifying filters are a proven technology and are capable of achieving a high level of nitrogen removal (3 mg/L on average), provided a high level of nitrification occurs in preceding steps. Two general types of denitrifying filters are available: downflow packed bed systems and upflow fluidized beds.

Downflow packed bed systems are deep bed sand filters operated to encourage attached microorganisms to denitrify. Methanol (or alternative organic carbon source) is added to provide a carbon source to aid denitrification. Packed beds provide adequate detention time and surface area to maintain anoxic conditions for denitrification to occur. The packed beds also act as effluent filters to remove suspended solids and improve effluent quality. Periodically, the beds must be backwashed and "bumped" with backwash water for a few seconds to release nitrogen gas which accumulates in the filter media and increases headloss through the media.

Upflow fluidized beds are columns containing sand that is constantly moving as it is fluidized. Denitrifying microorganisms attach to the sand as nitrified effluent flows upward through the column. This type of process is considered an attached growth and suspended growth process.

Figure 8-11 presents a schematic of denitrifying filters.

Denitrifying filters have the following advantages:

- Well-proven and reliable technology to meet total nitrogen limits.
- No significant environmental or public acceptance concerns.
- Potential for air emissions is minimal, as filters are enclosed in a building.

They have the following disadvantages:

- Moderate capital costs for new facilities and building enclosure.
- High O&M costs.
- Effluent pumping is typically required due to large headloss.
- Methanol (or an alternative organic carbon source) addition is required.

8.5 TECHNOLOGIES TO ACHIEVE LESS THAN 3 MG/L TOTAL NITROGEN

A. **Introduction.** Since the 1970's there is a significant amount of experience with removing nitrogen to levels of 5 to 7 mg/L. Since the late 1990's there is increasing experience with removing nitrogen to enhanced nitrogen removal levels of 3 mg/L on average. The need to treat municipal wastewater to levels below 3 mg/L is rare and thus there is limited experience with full-scale municipal systems. The stringent nitrogen limits of Cape Cod are forcing consideration of new technologies.

It is important to understand the limitations of removing nitrogen to levels below 3 mg/L. The nitrogen that remains in the effluent following enhanced nitrogen removal treatment processes consists of three forms: ammonia, oxidized nitrogen (typically nitrate), and organic nitrogen. In a system that is fully nitrifying, the ammonia will be less than 1 mg/L, perhaps as low as 0.2 to 0.5 mg/L. If the system has performed very well with denitrification, nitrate in the effluent should be less than 1 mg/L. Both ammonia and nitrate are soluble so filtration will not reduce them further. Organic nitrogen consists of both a soluble and a particulate form. The particulate form of organic nitrogen is associated with any biological floc that escapes in the effluent and is generally proportional to the level of suspended solids in the effluent. If filtration is provided, then the particulate organic nitrogen is removed and the soluble organic nitrogen is approximately 1 mg/L. The soluble organic nitrogen can be higher in treatment plants that receive waste from industries such as textile or dye plants or that receive a significant amount of septage. Thus, as the various forms of nitrogen in a filtered effluent are added together, the concentration approaches 3 mg/L as a limit unless some additional, more industrial treatment steps are taken to remove them.

B. **Technologies Used to Achieve Less Than 3 mg/L Total Nitrogen.** The technologies described below reduce the effluent total nitrogen by removing one of the three remaining fractions of nitrogen in the effluent in one of several ways:

1. **Adsorption.** Activated carbon may be used to adsorb soluble organics including carbon and nitrogen compounds. There are several processes to accomplish this. Granular activated carbon filters are available as either downflow gravity filters or pressure filters. Powdered activated carbon can be added to a stage of the activated sludge process to adsorb the organics while also retaining them in the process for possible further biological treatment. The Zimpro PACT system is an example of this type of process.

2. **Advanced Oxidation Technologies**. Advanced oxidation technologies work on the principle of breaking down the chemical bonds in the organic nitrogen (as well as other organic compounds) that make it difficult for the compound to be oxidized biologically. Once these bonds are broken down, the ammonia compound will be further metabolized by the enhanced nitrogen removal processes. There are two basic advanced oxidation technologies. One relies strictly on ultraviolet light and is referred to as direct photolysis. The organic compound would absorb the energy provided by the ultraviolet light, which causes the bonds to disassociate. The second type, which would be more applicable, utilizes a combination of ultraviolet light and

some type of oxidant, such as hydrogen peroxide or ozone. The ultraviolet light and oxidant produce hydroxyl (OH^-) radicals, which are very strong oxidants and will attack the bonds.

3. **Precipitation.** Chemical precipitation may be used to remove additional ammonia. If magnesium and phosphorus salts are added, the ammonia will be precipitated as a form of struvite.

4. **Ion Exchange.** Zeolite media has been used to remove the ammonium cation (NH_4^+). The media can be added as a slurry or can be used in a packed column. There are several commercial applications of this technology. The media is regenerated with a caustic salt water solution.

5. **Breakpoint Chlorination.** Breakpoint chlorination chemistry is well known and was applied early in the industry as a physical/chemical process for nitrogen removal. The process was found to be expensive and difficult to operate as the main process for removing all of the ammonia from a waste stream. However, it is more practical when treating only the ammonia remaining in the effluent of a biological treatment plant.

6. **Membrane Filtration.** Reverse osmosis membrane filtration is effective in removing additional organic nitrogen because the membranes are capable of blocking some of the higher molecular weight organic compounds. The system would also remove any nitrogen associated with effluent particulate solids.

C. **Summary.** These following technologies have been identified at this stage in the project to provide understanding on how additional technologies could be added to an enhanced nitrogen removal treatment system to achieve lower levels (less than 3 mg/L) of total nitrogen in the effluent. These are not conventional wastewater treatment technologies and would add greater costs to an overall system. These systems would typically need to be piloted with the treated water that would be coming from the enhanced nitrogen removal process to optimize the design of the system and to gain regulatory approval. These processes may also generate waste streams (side streams) that are difficult to manage and require special disposal requirements adding to operational costs.

8.6 TECHNOLOGIES TO REMOVE ENDOCRINE DISRUPTORS

A. **Recent Findings.** Recent studies by the United States Geologic Survey have focused attention on surface water quality of several rivers which receive large flows of treated wastewater effluent. The studies have indicated a high incidence of male fish exhibiting sexuality changes and have identified that several chemicals in the effluent (chemicals from pesticides, pharmaceuticals, etc.) may have had an adverse effect on the endocrine system of fish, causing the sexuality changes. These chemicals (often called endocrine disruptors as a category of chemicals) have received significant attention within the wastewater industry due to the potential future need to remove them from treated wastewater, although no limits for these chemicals currently exist.

The February 2007 issue of *Water Environment Research* published the results of a study that evaluated the ability of three types of wastewater treatment/water reclamation to remove these chemicals. The report focused on the following three types of tertiary treatment processes: coagulant-assisted granular media filtration; lime clarification/reverse osmosis; and microfiltration/reverse osmosis.

The removal rates of several specific endocrine disruptors varied among the treatment processes. However, the reverse osmosis processes were more effective than the coagulation/filtration process. Microfiltration combined with reverse osmosis was the most efficient of the processes. Additionally, the report stated that secondary treatment with enhanced biological nitrogen removal provided more removal of the chemicals than non-enhanced processes.

B. **Summary.** This new pollutant of concern (and the technologies that could be used to treat these chemicals) is identified at this stage of the project to provide an understanding that future treatment processes may need to be added to an enhanced nitrogen removal process as new limits are developed. A municipal wastewater treatment facility is the best location to plan to meet these future limits. On-site nitrogen removal systems and community cluster systems are not practical to remove these chemicals.

8.7 CONSIDERATIONS ON TREATMENT FOR PHOSPHORUS TECHNOLOGIES

Recent studies have indicated that phosphorus discharged upgradient of freshwater ponds can migrate through the soil with the groundwater to the ponds and cause nutrient enrichment in the ponds. Before these studies were completed, the conventional judgment was that the phosphorus became bound to the soil particles and did not migrate with the groundwater. If treated water recharge is to occur upgradient of a freshwater pond, phosphorus removal from the water may be required.

Phosphorus removal from wastewater is currently required for many regions of the United States. The treatment processes are well understood and phosphorus removal to 0.2 mg/L total phosphorus in the treated water is commonly attained at municipal treatment plants through a combination of biological uptake, chemical precipitation through the addition of iron or aluminum salts, and filtration.

8.8 DISINFECTION TECHNOLOGIES

A. **Introduction.** This section presents several alternatives for disinfection which might be required by MassDEP and should be considered as part of any new community/municipal wastewater treatment facilities in Eastham.

B. **Chlorination.** Chlorination can be provided by the addition of a number of chemicals, including sodium hypochlorite, calcium hypochlorite, gaseous chlorine, bromine chloride, and chlorine dioxide. Use of either sodium hypochlorite or calcium hypochlorite for disinfection is very similar and involves storage and feeding of hypochlorites in solution form. Hypochlorites are hazardous and corrosive, but these chemicals are safer than gaseous chlorine with respect to storage and overall management.

All chlorine compounds can combine with organic material and produce trihalomethanes, which have been proven to be carcinogenic in small quantities. The USEPA and MassDEP have established a drinking water standard of 0.1 ppm for trihalomethanes. Testing conducted on Cape Cod using treatment plant effluent disinfected with sodium hypochlorite does not indicate the formation of trihalomethanes above 0.1 parts per million (ppm). At the same time, there may be the perception of a public health concern for disinfection with chlorine compounds.

Sodium hypochlorite is the preferred method of chlorination and has the following advantages:

- The process can be controlled for feed dosages and chlorine residual.
- Minimal energy use.
- Low O&M costs, depending on the cost of sodium hypochlorite.

Use of chlorination for disinfection has the following disadvantages:

- A large contact tank is needed.
- There may be potential perception of groundwater contamination with trihalomethanes.
- The storage and handling of sodium hypochlorite can be a safety hazard.
- Sodium hypochlorite has a limited shelf life.

C. **Ozone.** Ozone has been found to be highly effective in disinfection and has fewer potential adverse environmental impacts on receiving waters and water supplies. Ozone must be generated on-site, which normally involves the use of high voltage electrodes and pure oxygen. Ozone is then transferred from the gas phase to the liquid phase with diffusers and closed contactors. The off-gases from the contactor must be treated thermally to destroy excess ozone, which is toxic.

Ozone presents less environmental concern than chlorination because ozone rapidly dissipates to oxygen after application, leaving no ozone residual and adding dissolved oxygen to the treatment plant effluent. Ozone, however, can produce toxic mutagenic and/or carcinogenic compounds. Unlike chlorine, ozone does not produce a residual concentration that can be measured and used as an instantaneous indication of satisfactory disinfection.

The cost to produce ozone on site is high, resulting from the high capital cost of generation equipment and high energy requirements. Ozonation is labor intensive because the system is complex and difficult to operate and maintain.

Disinfection with ozone has the following advantages:

- Ozone dissipates rapidly to oxygen, leaving no ozone residual.
- Ozone adds dissolved oxygen to treatment plant effluent.
- Fewer adverse environmental impacts compared to chlorination.

It has the following disadvantages:

- Ozone is toxic and can produce mutagenic and/or carcinogenic compounds even though it rapidly dissipates to oxygen.
- High capital costs associated with generating equipment.
- High energy usage to generate ozone.
- Complex operation and maintenance.
- High O&M costs.
- Destruction of off-gases from contactors is required.
- Does not produce a monitorable residual.

D. **Ultraviolet Radiation.** Unlike the previous alternatives, ultraviolet radiation provides disinfection without the use of chemicals. Ultraviolet light provides radiation which penetrates bacterial cell walls and viruses and inactivates them and prevents them from reproducing. Without the use of chemicals, no toxic residuals are produced. The ultraviolet bulbs are contained in racks or modules which are submerged in channels. Required contact time with the bulbs is short.

Effluent suspended solids can interfere with disinfection efficiency by preventing light transmission in the water and penetration of the cell wall; therefore, a high quality effluent is required prior to the ultraviolet disinfection. The ultraviolet bulbs foul over time and must be periodically removed and cleaned, which is accomplished by dipping the rack of bulbs in a chemical bath or utilizing a submerged mechanical wiper blade system. The bulbs must be periodically replaced, which adds to the O&M costs; however, ultraviolet disinfection has been found to be cost competitive with chlorination.

Ultraviolet disinfection has the following advantages:

- No adverse environmental impacts.
- Minimal space requirements with short contact time.
- Ease of operation and maintenance.
- Cost competitive with other disinfection techniques.
- Well-proven effectiveness.

It has the following disadvantages:

- Suspended solids, turbidity, and color can interfere with the effectiveness of disinfection.
- High quality effluent required prior to UV disinfection.
- Periodic cleaning and replacement of bulbs is required.
- Limited process control.
- Does not produce a monitorable residual.
- High energy user.

8.9 RESIDUALS MANAGEMENT

A. **Introduction.** The purpose of this section is to identify technologies that could be used to properly treat and dispose of residuals from new community/municipal wastewater treatment processes. Residuals are byproducts of wastewater treatment and are often difficult to handle, expensive to dispose of, and can be a source of odors. The following is a description of the various types of residuals associated with community/municipal sanitary wastewater:

1. **Septage.** Septage is comprised of wastewater solids that accumulate in septic tanks, tights tanks, and cesspools, and includes sludge, scum, and liquids.

2. **Trap Grease.** Trap grease is the material that is periodically pumped out of grease traps and is a combination of solid floatable grease, settleable solids, and water. Trap grease is difficult to handle, difficult to dispose of, and should be isolated from other treatment processes because it fouls piping, valves, and other treatment equipment.

3. **Screenings and Grit.** Screenings and grit are byproducts of treating wastewater, septage, and trap grease. Screenings are large solid objects removed from wastewater in bar screens during preliminary treatment. Grit consists primarily of sand and gravel and is also typically removed during the preliminary treatment process. Removing screenings and grit from wastewater and sludge treatment processes is important to prevent damage to pumps, valves, and pipelines.

4. **Sludge.** Sludge (sometimes referred to as biosolids) is the organic material removed from wastewater treatment processes. Wastewater sludge is solid material that settles by gravity in a primary wastewater treatment process, or is a combination of microorganisms and organic material generated in advanced treatment processes. Sludge is produced as a liquid and typically has a solids concentration of 5,000 to 20,000 mg/L (0.5 to two percent total solids). It is typically thickened and disposed of at regional disposal facilities at a concentration of five percent total solids. Also, it can be dewatered and disposed of at regional disposal facilities as a sludge cake at a concentration of 15 to 25 percent total solids. It can also be dewatered and composted to produce a soil conditioner material of approximately 35 to 50 percent total solids.

B. **Screenings and Grit Disposal.** Screenings and grit are typically generated at the headworks of centralized wastewater treatment facilities. Screenings and grit from a new wastewater treatment facility would most likely be combined and disposed at an approved location.

C. **Sludge Processing Technologies.** Sludge is a byproduct of community/municipal wastewater treatment processes and must be treated properly to avoid odors, reduce disposal costs, and minimize potential risks to human health. Sludge processing technologies are divided into the following categories and outlined in Figure 8-12:

- Sludge thickening
- Sludge dewatering
- Sludge stabilization and composting
- Sludge disposal

1. **Sludge Thickening.** Sludge thickening is a process to concentrate sludge by removing a portion of the liquid fraction. Sludge thickening reduces transportation and disposal costs and facilitates additional sludge treatment processes, including dewatering and

stabilization. Sludge thickening can be accomplished by several processes. The simplest thickening process involves storing sludge in an aerated tank and periodically stopping aeration to allow sludge to settle and excess liquid to be decanted. Other thickening processes are more complicated and utilize equipment such as filters, centrifuges, and rotating drums. Thickening with these types of mechanical equipment (mechanical thickening) often requires a covered process building, odor control facilities, and additional process equipment such as feed pumps and piping. Mechanical thickening also typically requires the addition of chemicals, such as polymer, to condition the sludge and facilitate the thickening process.

2. **Sludge Dewatering.** Sludge dewatering is a physical process used to reduce the water content of thickened sludge. Dewatered sludge, also known as sludge cake, has the consistency of moist sawdust and requires less volume for storage or transportation to a disposal site. Dewatering is commonly performed using belt filter presses or centrifuges. Polymer is added to improve the dewatering process.

3. **Sludge Stabilization and Composting.** Sludge is stabilized to reduce pathogens, odors, and the potential for the sludge to biologically decay. Sludge stabilization processes can be used prior to or following sludge dewatering. Common sludge stabilization technologies include composting, digestion, alkaline stabilization, and heat treatment and drying and are discussed as follows:

a. **Composting.** Composting is a biological sludge stabilization process that destroys pathogens, reduces the water and organic solids content of dewatered sludge, and produces a granular, soil-like material. Sludge composting processes typically include the following three steps:

1) Dewatered sludge is mixed with a bulking agent such as wood chips, yard waste, or sawdust.

2) The mixture is aerated or regularly mixed, which increases the temperature of the mixture, killing pathogens and degrading the highly volatile solids of the sludge.

3) The composted material is cured and stored for distribution.

Finished compost can be distributed to the public if it meets criteria established by MassDEP regulations. Composting is typically most successful if the sludge to be composted has already been digested because the material is partially stabilized, there is less potential for generation of odors, and the sludge is easier to handle. Although composting provides a beneficial reuse of sludge, it is usually not cost effective for low sludge flows. Sludge composting facilities often consist of large covered structures to shelter the compost machinery and odor control facilities. Land areas and capital costs are usually relatively high for composting facilities.

b. **Digestion.** Digestion is a biological stabilization process that reduces the number of pathogens and the overall solids content of sludge through the use of microorganisms. The microorganisms feed on the organic material in the sludge and are utilized in two types of sludge digestion processes: anaerobic digestion and aerobic digestion. Digested sludge can be dewatered, composted, or disposed of at a regional facility. Anaerobic digestion produces methane gas that can be used as a fuel source.

Anaerobic and aerobic sludge digestion processes typically include two or more large covered tanks. Thickened sludge is fed into the tanks where anaerobic or aerobic microorganisms decompose the sludge. Mixing and aeration equipment is required to improve the digestion process and maintain either an anaerobic or aerobic environment. The digestion process also requires covered buildings to protect process equipment and odor control facilities. Sludge digestion is not cost effective for small sludge flows.

c. **Alkaline Stabilization.** Alkaline stabilization is a process in which dewatered sludge is combined with an alkaline material, such as cement kiln dust or lime, to raise the pH, raise the temperature, and reduce the water content of the sludge. Raising the pH and temperature of the sludge creates an environment which is hostile for pathogen growth and reproduction. Alkaline stabilization, like composting, can produce a material that meets MassDEP's requirements for distribution to the public.

The primary market for an alkaline stabilized sludge is the agricultural industry. The alkaline stabilized sludge has alkalinity and nutrients that are useful for growing corn and other crops; however, this type of agricultural market does not exist on Cape Cod.

The facilities required for alkaline stabilization include enclosed areas for storing alkaline materials, processing the sludge-alkaline material mixture, and storing the final product. Equipment requirements include screw conveyors for transferring the alkaline materials, a mixing unit that combines dewatered sludge and alkaline material, and a drying process for the blended material. Land area requirements and capital and operations costs are comparable to those of a composting facility. Alkaline stabilization is typically not cost effective for small sludge flows in areas where there is not a market for the final product.

d. **Heat Treatment and Drying.** Heat treatment and drying are thermal stabilization processes that involve heating sludge under pressure to disinfect and dry the sludge. The resulting material is easier to dewater and may be dried to produce a powdered or pelletized product, which can be used as a fertilizer or soil conditioner.

These processes generally have high capital costs, high level of complexity, high energy usage and operation costs, and are usually poorly received by the public due to air emissions. In addition, thermal processes require a continuous flow of sludge to keep the process running and are therefore usually not cost effective for low sludge flows.

D. **Sludge Disposal Alternatives.**

1. **Thickening and Disposal at a Regional Facility.** This alternative would involve the transportation and disposal of thickened sludge at a regional facility. This would require the construction of sludge storage and thickening facilities. The thickened sludge would be transported to a regional facility for disposal (i.e., Woonsocket, Rhode or Worcester, Massachusetts).

This alternative has the following advantages:

- Use of one common sludge processing facility.
- Minimizes capital costs and equipment operational costs.

This alternative has the following disadvantages:

- May require transportation of unthickened sludge to a separate facility.

2. **Sludge Dewatering and Disposal at a Regional Facility.** Using this alternative, a new facility would dewater the sludge and dispose of the sludge cake at a regional facility.

This alternative has the following advantages:

- Disposal costs for sludge cake are less than those for thickened liquid sludge.
- Thickened sludge could be received and processed at a regional facility.

This alternative has the following disadvantages:

- Belt filter presses or centrifuges are the most common and economical dewatering processes, but they are more expensive than simple thickening equipment.
- There are few regional disposal facilities that accept sludge cake and the cost savings with sludge cake disposal do not offset the higher cost to produce it.
- The sludge dewatering process provides a greater potential for release of odors.

3. **Sludge Dewatering, Composting, and Distribution to the Public.** This alternative involves the construction of sludge dewatering and composting facilities, with the primary goal to produce a material that could be distributed to the public. Although it is unknown if there would be sufficient demand for sale of these materials in Eastham, experience indicates that the public will pick up and use the material if it is free and of good quality.

Composting and distribution of compost would have the following advantages:

- The Town would not have to pay for sludge disposal.
- Beneficial reuse is provided.
- The Town has more control over sludge disposal and is not dependent on a regional sludge disposal facility.
- Sludge generated and thickened at multiple facilities could be dewatered and composted at one centralized location.

This alternative would have the following disadvantages:

- Construction and O&M costs are typically highest for this alternative.
- Regular sampling, analysis, and reporting to MassDEP is required.
- The potential for odors is increased and adjacent property owners may not welcome this type of process.
- Large land area is required.

4. **Land Application of Sludge.** This alternative involves the thickening and/or dewatering of sludge and subsequent spreading of sludge (in very controlled application rates) onto and into the land. The land is then seeded with an agricultural crop to utilize the sludge's nutrients and turn it into soil material. This type of sludge disposal is common in the Midwestern United States, where there are large farms that welcome the nutrients. It has also been used in other places to produce inexpensive topsoil for the construction of landfill caps. This method of sludge disposal is not recommended for Eastham because there are no large agricultural lands nearby that could use (or want) the sludge. Also, sludge contains significant amounts of nitrogen, which typically does not lend itself to application in the many watersheds to sensitive coastal embayments.

Land application would have the following advantages:

- High nutrient value for crops.

This alternative would have the following disadvantages:

- High nitrogen content.
- Minimal agricultural land.