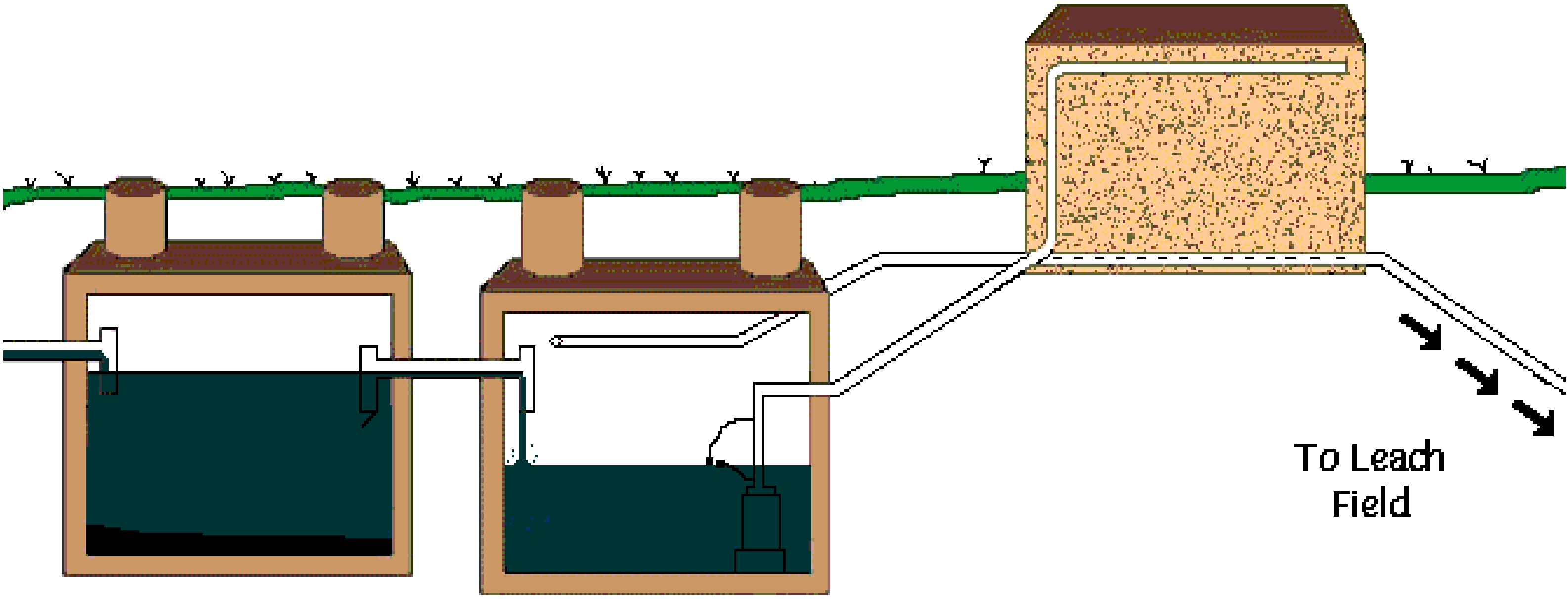
A Compendium of Information on Alternative Onsite Septic System Technology in Massachusetts



From the Authors

Beginning in 1994, the Barnstable County Department of Health and the Environmental began to publish a series of newsletters and fact sheets on alternative onsite septic system technologies in Barnstable County. The purpose of the newsletters was to familiarize boards of health with various aspects of alternative onsite septic system technologies, their proper application, and their permitting requirements. Since that time, we have received a number of requests from individuals and boards of health elsewhere in the state for copies of back issues of these documents. Realizing that much of the information, particularly in earlier issues, was dated, the authors were reluctant to reprint and distribute earlier issues. Through the support of the ***Massachusetts Coastal Zone Management*** however, we were able to produce this document, which is a compendium of information on the various technologies discussed in the newsletters with most of the time-sensitive information removed. Although we have attempted to remove as much of the time-sensitive information in this document as possible, the reader should be aware that the approvals for the various technologies are subject to change. The changes in permitting status are generally sent to local boards of health. Accordingly, engineers and system designers are urged to check with this resource before planning a system using the alternative technologies. In addition, the newsletters and this compendium should not be used for design purposes. Where appropriate, the authors have directed the reader where to obtain more specific design guidance, since the purpose of these documents remains the introduction and the explanation of the various technologies to boards of health. The reader should also understand that the mention of any product, method, company, distributor of products, or the like, does not constitute an endorsement of such by our department or any other government agency. Any opinions expressed in this document do not necessarily reflect that of any government agency and the authors take responsibility for the accuracy of the information presented herein. This document is a compendium of issues 1 though 10 of the *Alternative Septic System Newsletter, and Factsheets* as of May, 1997. Subsequent issues of the newsletter will continue to provide up-to-date information on new technologies, as the information becomes available.

The authors wish to thank the Massachusetts Department of Environmental Protection, specifically Christos Dimisioris and YuHsia Boothroyd of the Division of Wastewater Management, in Boston for their assistance in making this document as accurate as possible. The publication of the *Alternative Septic System Newsletter,* from which this document is derived has received support from the ***Massachusetts Bays Project.*** The newsletter and other outreach efforts, including a World Wide Web page (http://www.capecod.net/alternative septic/) that features the newsletters, has received support from the Massachusetts Department of Environmental Protection under the Federal 319(b) Grant Program. We gratefully acknowledge this past and present support. The authors also gratefully acknowledge the efforts of staff members Rick Judd and Sean Foss for their contributions in researching and preparing various sections of the document. Various manufacturers of products are acknowledged for providing some of the illustrations herein. This report is has no copyright protection and may be copied freely and distributed.

George Heufelder & Susan Rask
Barnstable County Department of Health and the Environment
Superior Courthouse, Route 6A
Barnstable, Massachusetts 02630

Introduction

Until relatively recently, technology for the onsite treatment of household sanitary waste in Massachusetts was relatively "standard" , involving in most cases a septic tank for the settling of solids and mineralization[1] of wastes, and a leachfield for the safe disposal of the liquefied waste in appropriate locations away from points of possible human exposure. A frank assessment of this technology is that its primary focus is on disposal, following some rudimentary treatment. Ultimate "treatment" in standard systems is primarily due to dilution, dispersion and retention in underlying soils until pathogens are rendered harmless. The lack of focus on actual treatment of waste onsite is primarily attributable to the thought that the onsite septic system was a temporary means of waste disposal until such time as the community constructed centralized sewage treatment facilities. With the withdrawal of federal support for centralized wastewater collection and treatment facilities and the economic realities associated with such, communities now recognize that the onsite septic system is evolving into the long-term wastewater solution for many areas. The problem generally recognized under the paradigm of onsite septic

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[1] Mineralization is the biologically-mediated conversion of solid waste into soluble components.

system use is that research continues to verify that certain resource areas, such as drinking water aquifers and watersheds of marine and freshwater resources, can no longer tolerate the mere disposal of wastes. Many communities are now inquiring as to what options are available to actually treat wastewater for harmful constituents near their source of generation - onsite. Until recently, however, options for the widespread use of "alternative" onsite septic systems were fairly limited.

In March 1995, the landscape of alternative septic system use in Massachusetts was dramatically changed. Up to this point, alternative methods for disposing of sanitary waste onsite were generally rare; most installations involved composting toilet technology that was allowed at the time. The March 1995 changes to the onsite septic system regulations in Massachusetts (CMR 15.00, commonly referred to as Title 5) however, describes the various approval processes for more widespread use of alternative onsite septic system technologies. These past two years have witnessed both a clarification of the permitting process and a proliferation of the technologies statewide.

The quest for the better "mousetrap" in onsite septic system technology in Massachusetts began in the early 1990's. In February 1992, the Waquoit Bay National Estuary Research Reserve (WBNERR) sponsored the first conference on alternative onsite septic system (AOSS) technology to be held in Barnstable County. As participants heard of the various states' programs for alternative septic system use, many wondered what was preventing their use in Massachusetts. These questions were somewhat answered, however, as the stories from various states revealed the two-edged-sword nature of alternative septic systems. On the one side, AOSS can address both limiting physical conditions (soil percolation rate or distance to groundwater, space, etc.) and pollution problems (nitrogen in particular). On the other side AOSS technology could, without adequate planning controls, open up new areas to development that were otherwise restricted in part by then-present Title 5 constraints.

Nevertheless, 1993-1997 has witnessed a number of research and demonstration projects to demonstrate the efficacy of AOSS technologies. A particular aspect of AOSS introduction to Massachusetts at this point bears mention. In many other parts of the country, AOSS were introduced primarily to address the issue of poorly percolating or otherwise limiting soil conditions as opposed to addressing the various nonpoint pollution issues of onsite septic system use. Many USEPA studies focusing on marine and estuarine water quality (including two in Massachusetts - the Buzzards Bay Project and the Massachusetts Bays Project), however, confirm the need to address the issues of nitrogen and pathogen contribution to marine systems from onsite septic systems. Accordingly, the focus of most of the demonstration projects in Massachusetts has been to demonstrate the reduction of both pathogens and nitrogen.

The first demonstration project in Massachusetts for AOSS continues until today in the City of Gloucester. Faced with the pressure to expand their sewage treatment facility, city officials there sought to demonstrate that onsite solutions were feasible both from the treatment aspects, as well as economically. Since then, demonstration projects have proceeded under support from the Massachusetts Department of Environmental Protection (under the 319(b) Program - four systems are being installed between the towns of Provincetown, Eastham, Wellfleet, and Truro), the Massachusetts Bays Program (five systems have been installed in Wellfleet under the MiniBays subprogram), the Buzzards Bay Program (two systems have been installed in that watershed, with one more soon to be installed), and WBNERR (four different technologies have been installed and are being monitored under the National Onsite Demonstration Program of EPA). In addition, a cooperative project between the Barnstable County Department of Health and the Environment, Dr. Brian Howes of the Center for Marine Science and Technology (CMAST) of the University of Massachusetts at Dartmouth, and the Buzzards Bay Project, endeavors to construct an AOSS technology testing facility under a program called Environmental Technology Initiative (ETI). The testing facility is to be constructed at the Massachusetts Military Reservation.

If you have been a regular reader of the newsletter from which this document is derived, you will notice that the following chapters do not, for the purpose of logical presentation of the information, contain the following two "warnings", which were sporadically echoed in the newsletter. The first warning relates to the fact that, although often not officially stated, Title 5 has in the past been used as a de facto density control. As AOSS develops, municipalities should heed the "heads up" that should have already been heard. If proper planning instruments are not in place to articulate what a community wants to be (i.e. what densities of residential housing it desires or can support), it is quite possible that the advancing technologies will allow higher density of development than communities might desire. Already, relating to the issue of nitrogen loading, proponents wishing to develop at higher density can obtain "credits" for doing so by using AOSS (see chapter on permitting). The second "warning" is more specific to Boards of Health and other individuals who are applying AOSS technology. The caution here is merely to understand the technology before applying it to a specific problem. The most common misapplication of AOSS we have seen is the situation where a Board of Health allows the installation of AOSS to compensate for the inability of a proponent to meet a setback requirement of 100 feet from a watercourse. In these instances we have seen denitrifying technologies allowed to compensate for a setback that was predicated on pathogen (specifically virus) concerns. In short, unless the technology being proposed addresses the issue that is central to your setback requirement, it should not be considered a compensating action by the proponent.

In closing to this introduction, the authors would again like to remind the reader that this compendium is not the "final word" on AOSS. Through various funding supports, the Barnstable County Department of Health and the Environment intends to continue to produce the newsletter from which this document was derived. In the next year, support is provided in part by the Massachusetts Bays Project and the Department of Environmental Protection through a 319(b) grant to our Department. The authors again wish to express thanks to all those individuals, notably the staff of DEP Division of Wastewater Management who continue to contribute to the accuracy of the documents.

BASICS OF WASTEWATER TREATMENT

Before you go on to read about the individual technologies discussed later in this document, it is helpful to understand some of the basics of wastewater treatment. You will see terms like BOD, total suspended solids, nitrification, and denitrification frequently when discussing wastewater treatment. It is important to understand what each of these terms mean and how each relates to the wastewater treatment process. Some very basic processes of wastewater treatment are also briefly discussed. If you understand the theory behind these basic treatment processes it is easy to see how and why the processes are applied in the various alternative technologies discussed later.

BASIC CONSTITUENTS OF WASTEWATER

Biochemical oxygen demand

One of the most commonly measured constituents of wastewater is the **biochemical oxygen demand, or BOD.** Wastewater is composed of a variety of inorganic and organic substances. Organic substances refer to molecules that are based on carbon and include fecal matter as well as detergents, soaps, fats, greases and food particles (especially where garbage grinders are used). These large organic molecules are easily decomposed by bacteria in the septic system. However, oxygen is required for this process of breaking large molecules into smaller molecules and eventually into carbon dioxide and water. The amount of oxygen required for this process is known as the biochemical oxygen demand or BOD. The Five-day BOD, or BOD_5, is measured by the quantity of oxygen consumed by microorganisms during a five-day period, and is the most common measure of the amount of biodegradable organic material in, or strength of, sewage.

BOD has traditionally been used to measure of the strength of effluent released from conventional sewage treatment plants to surface waters or streams. This is because sewage high in BOD can deplete oxygen in receiving waters, causing fish kills and ecosystem changes. Based on criteria for surface water discharge, the secondary treatment standard for BOD has been set at 30 mg BOD/L (i.e. 30 mg of O_2 are consumed per liter of water over 5 days to break down the waste).

However, BOD content of sewage is also important for septic systems. Sewage treatment in the septic tank is an anaerobic (without oxygen) process; in fact, IT IS ANAEROBIC BECAUSE SEWAGE ENTERING THE TANK IS SO HIGH IN BOD THAT ANY OXYGEN PRESENT IN THE SEWAGE IS RAPIDLY CONSUMED. Some BOD is removed in the septic tank by anaerobic digestion and by solids which settle to the bottom of the septic tank, but much of the BOD present in sewage (especially detergents and oils) flows to the leaching field. Because BOD serves as a food source for microbes, BOD supports the growth of the microbial biomat which forms under the leaching field. This is both good and bad. On the one hand, a healthy biomat is desired because it is capable of removing many of the bacteria and viruses in the sewage so that they do not pass to the groundwater. The bacteria in a healthy biomat also digest most of the remaining BOD in the sewage. Too much BOD, however, can cause excessive growth of bacteria in the biomat. If the BOD is so high that all available oxygen is consumed (or if the leaching field is poorly aerated, as can be the case in an unvented leaching field located under pavement or deeply buried) the biomat can go anaerobic. This causes the desirable bacteria and protozoans in the biomat to die, resulting in diminished treatment of the sewage. Low oxygen in the biomat also encourages the growth of anaerobic bacteria (bacteria which do not require oxygen for growth). Many anaerobic bacteria produce a mucilaginous coating which can quickly clog the leaching field. Thus, excess BOD in sewage can cause a leaching field to function poorly and even to fail prematurely.

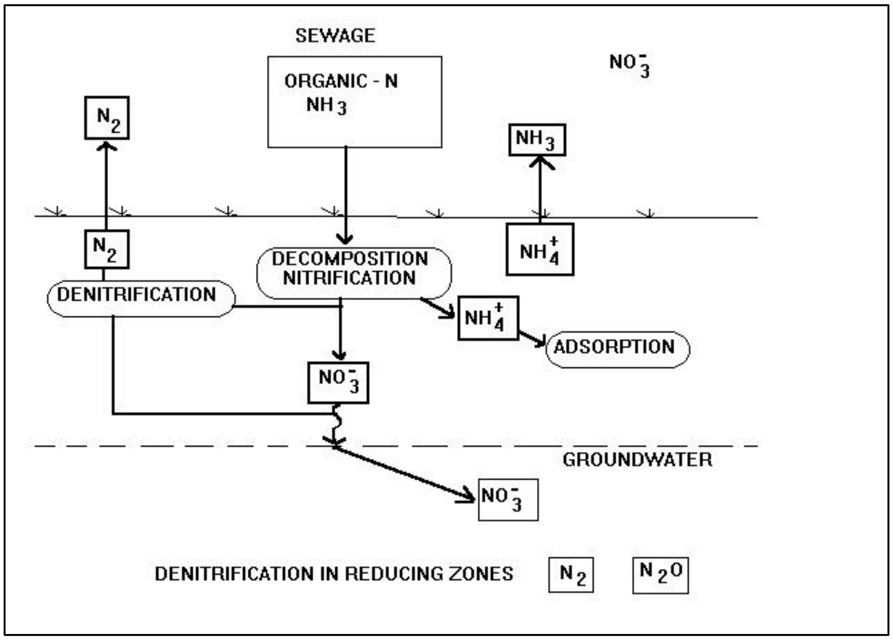
Many of the enhanced treatment technologies discussed later in this document were designed specifically to reduce BOD in treated sewage. BOD removal can be especially important where sewage effluent flows to a leaching field in tight soils. Tight soils are usually composed of silts and clays (particle size < 0.05 millimeter). These small soil particles are tightly packed and the pore space between them is small. Reducing BOD means that the sewage will support the growth of less bacteria and therefore the effluent will be better able to infiltrate tight soils. Many enhanced treatment technologies that remove BOD were designed specifically to enhance disposal of effluent in tight silt or clay soils.

BOD is fairly easy to remove from sewage by providing a supply of oxygen during the treatment process; the oxygen supports bacterial growth, which breaks down the organic BOD. Most enhanced treatment units described incorporate some type of unit, which actively oxygenates the sewage to reduce BOD. This unit is often located between the septic tank and the leach field. Or, it can be located within the septic tank in a specific area where oxygen is supplied. Reduction of BOD is a relatively easy and efficient process, and results in sewage of low BOD flowing to the leaching field. It is important to note, however, that low BOD in sewage may result in a less effective biomat forming under the leaching field.

It is also important to note that BOD serves as the food source for the denitrifying bacteria, which are needed in systems where bacterially-mediated nitrogen removal takes place. In these situations BOD is desired, as the nitrification/denitrification process cannot operate efficiently without sufficient BOD to support the growth of the bacteria which accomplish the process.

Total suspended solids

Domestic wastewater usually contains large quantities of suspended solids that are organic and inorganic in nature. These solids are measured as **Total Suspended Solids or TSS** and are expressed as mg TSS/ liter of water. This suspended material is objectionable primarily because it can be carried with the wastewater to the leachfield. Because most suspended solids are small particles, they have the ability to clog the small pore spaces between soil grains in the leaching facility. There are several ways to reduce TSS in wastewater. The simplest is the use of a septic tank effluent filter, such as the Zabel filter (several other brands are available). This type of filter fits on the outlet tee of the septic tank. It is made of PVC with various size slots fitted inside one another. The filter prevents passage of floating matter out of the septic tank and, as effluent filters through the slots, fine particles are also caught. Many types of alternative systems are also able to reduce TSS, usually by the use of settling compartments and/or filters using sand or other media.



Total nitrogen

Nitrogen is present in many forms in the septic system. Most nitrogen excreted by humans is in the form of organic nitrogen (dead cell material, proteins, amino acids) and urea. After entering the septic tank, this organic nitrogen is broken down fairly rapidly and completely to ammonia, NH_3, by microorganisms in the septic tank. Ammonia is the primary form of nitrogen leaving the septic tank. In the presence of oxygen, bacteria will break ammonia down to nitrate, NO_3. In a conventional septic system with a well aerated leaching facility, it is likely that most ammonia is broken down to nitrate beneath the leaching field.

Nitrate can have serious health effects when it enters drinking water wells and is consumed. Nitrate and other forms of nitrogen can also have deleterious effects on the environment, especially in coastal areas where excess nitrogen stimulates the process known as eutrophication. For this reason, many alternative technologies have been designed to remove total nitrogen from wastewater. These technologies use bacteria to convert ammonia and nitrate to gaseous nitrogen, N_2. In this form nitrogen is inert and is released to the air.

Biological conversion of ammonia to nitrogen gas is a two step process. Ammonia must first be oxidized to nitrate; nitrate is then reduced to nitrogen gas. These reactions require different environments and are often carried out in separate areas in the wastewater treatment system.

The first step in the process, conversion of ammonia to nitrite and then to nitrate, is called **nitrification** ($NH_3 \rightarrow NO_2 \rightarrow NO_3$). The process is summarized in the following equations:

$$NH_4 + {}^{3}/_{2}\,O_2 \rightarrow NO_2^- + 2H^+ + H_2O$$

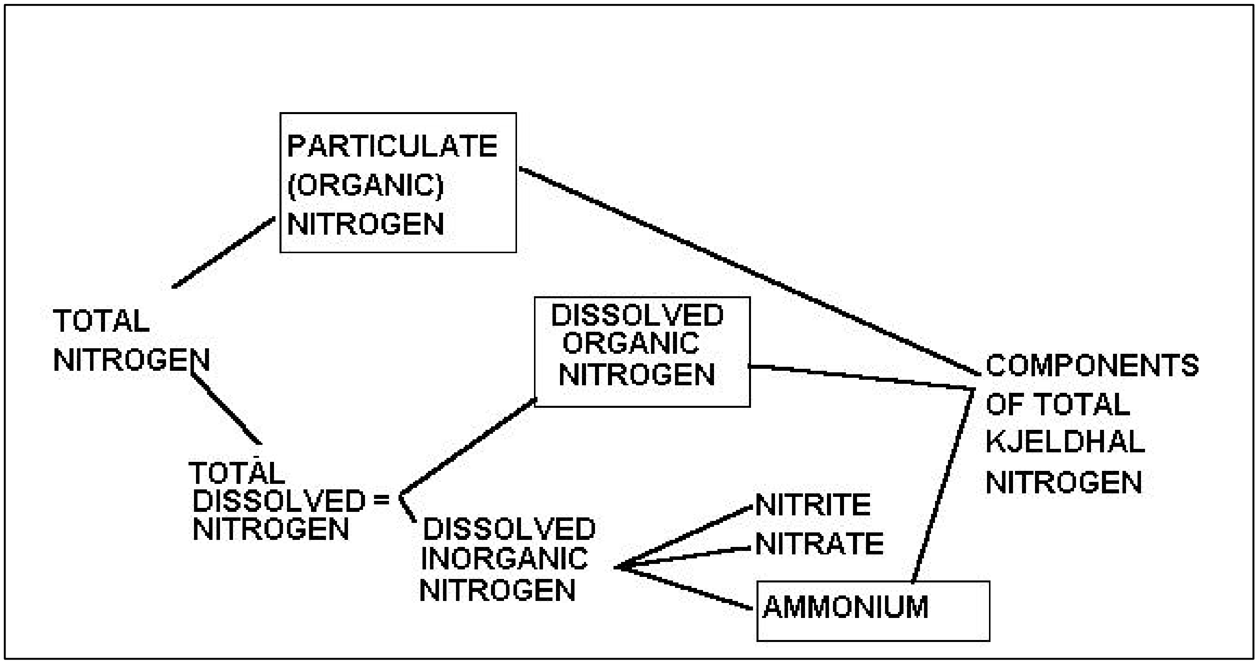
$$NO_2^- + {}^{1}/_{2}O \rightarrow NO_3^-$$

It is important to note that this process requires and consumes oxygen. This contributes to the BOD or biochemical oxygen demand of the sewage. The process is mediated by the bacteria *Nitrosomonas* and *Nitrobacter* which require an aerobic (presence of oxygen) environment for growth and metabolism of nitrogen. Thus, **the nitrification process must proceed under aerobic conditions.**

The second step of the process, the conversion of nitrate to nitrogen gas, is referred to as **denitrification**. This process can be summarized as:

$$NO_3^- + {}^{5}/_{6}\,CH_3OH \rightarrow {}^{1}/_{2}\,N_2 + {}^{5}/_{6}\,CO_2 + {}^{7}/_{6}\,H_2O + OH^-$$

This process is also mediated by bacteria. For the reduction of nitrate to nitrogen gas to occur, the dissolved oxygen level must be at or near zero; **the denitrification process must proceed under anaerobic conditions**. The bacteria also require a carbon food source for energy and conversion of nitrogen. The bacteria metabolize the carbonaceous material or BOD in the wastewater as this food source, metabolizing it to carbon dioxide. This in turn reduces the BOD of the sewage, which is desirable. However, if the sewage is already low in BOD, the carbon food source will be insufficient for bacterial growth and denitrification will not proceed efficiently.



Nitrogen can be measured in a variety of ways. The standard of using Kjeldal nitrogen has sometimes been replaced by measuring other species of nitrogen. Above is an illustration of the various components of nitrogen you may see measured. The standard measure of Kjeldal can be arrived at by computation.

Clearly, any wastewater treatment unit that is going to remove nitrogen by the nitrification/denitrification process must be designed to provide both aerobic and anaerobic areas so that both nitrification and denitrification can proceed. As you look at the nitrogen removal technologies discussed later in this document, you will see how various designs have attempted to solve this problem in some unique and interesting ways.

Phosphorus

Phosphorus is a constituent of human wastewater, averaging around 10 mg/liter in most cases. The principal forms are organically bound phosphorus, polyphosphates, and orthophosphates. Organically bound phosphorus originates from body and food waste and, upon biological decomposition of these solids, is converted to orthophosphates. Polyphosphates are used in synthetic detergents, and used to contribute as much as one-half of the total phosphates in wastewater. Massachusetts has banned the sale of phosphate-containing clothes washing detergent, so phosphorus levels in household wastewater have been reduced significantly from previous levels. Most household phosphate inputs now come from human waste and automatic dishwasher detergent. Polyphosphates can be hydrolyzed to orthophosphates. Thus, the principal form of phosphorus in wastewater is assumed to be orthophosphates, although the other forms may exist. Orthophosphates consist of the negative ions PO_4^{3-}, HPO_4^{2-}, and $H_2PO_4^-$. These may form chemical combinations with cations (positively charged ions).

It is unknown how much phosphorus is removed in a conventional septic system. Some phosphorus may be taken up by the microorganisms in the septic system and converted to biomass (of course, when these microorganisms die the phosphorus is re-released, so there really is no net loss of phosphorus by this mechanism). Any phosphorus which is removed in the septic system probably is removed under the leaching facility by chemical precipitation.

At slightly acidic pH (as is found in the soils of Cape Cod and most of New England), orthophosphates combine with tri-valent iron or aluminum cations to form the insoluble precipitates $FePO_4$ and $AlPO_4$.

$$Fe^{3+} + (H_nPO_4)^{(3-n)} \rightarrow FePO_4 + nH^+$$

$$Al^{3+} + (H_nPO_4)^{(3-n)} \rightarrow AlPO_4 + nH^+$$

Domestic wastewater usually contains only trace amounts of iron and aluminum. However, the sandy soil of Cape Cod frequently contains significant amounts of iron bound to the surface of sand particles. It is likely that this iron binds with phosphorus and causes some removal of total phosphorus below the leaching facility.

One caveat must be added here. If the soil below the leaching facility becomes anaerobic, iron may become chemically reduced (changed to the Fe^{2+} form), which is soluble and able to travel in groundwater. In this case, the iron phosphate compounds may breakdown and phosphorus may also become soluble. Anaerobic conditions under the leaching facility can occur when the leaching facility is not well aerated, when there is a small vertical separation to groundwater, or when BOD in the sewage is so high that all oxygen present is depleted to oxidize BOD. In the conditions found on Cape Cod, the best method for maximizing phosphorus removal is probably to locate the leaching facility well above groundwater (>5 feet vertical separation) thereby providing a well-aerated area under the leaching field. To date, no alternative on-site technologies are capable of significant phosphorus removal. However, many are trying to achieve this goal and it is likely that within the next few years we may begin to see some technologies that are successful at phosphorus removal.

BASICS OF SEWAGE TREATMENT

The treatment of sewage is largely a biochemical operation, where chemical transformations of the sewage are carried out by living microorganisms. Different environments favor the growth of different populations of microorganisms and this in turn affects the efficiency, end products, and completeness of treatment of the sewage. Sewage treatment systems, whether they are standard septic systems or more advanced treatment technologies, attempt to create specific biochemical environments to control the sewage treatment process.

Three basic types of biochemical transformations occur as sewage is treated. The first is the removal of soluble organic matter. This is composed of dissolved carbon compounds such as detergents, greases, and body wastes, which make up much of the BOD content of the sewage. The second is the digestion and stabilization of insoluble organic matter. These are the sewage solids, such as body wastes and food particles, which make up the remainder of the BOD. The third is the transformation of soluble inorganic matter such as nitrogen and phosphorus.

The two major biochemical environments in which sewage treatment is carried out are termed **Aerobic** and **anaerobic** environments. An aerobic environment is one in which dissolved oxygen is available in sufficient quantity that the growth and respiration of microorganisms is not limited by lack of oxygen. An anaerobic environment is one in which dissolved oxygen is either not present or its concentration is low enough to limit aerobic metabolism. The biochemical environment has a profound effect upon the ecology of the microbial population, which treats the sewage. Aerobic conditions tend to support entire food chains from bacteria up to rotifers and protozoans. These microbes beak down organic matter using many metabolic pathways based on aerobic respiration with carbon dioxide as the main end product. Anaerobic conditions favor the growth of primarily bacterial populations and produce a different variety of end products, discussed below.

Anaerobic Digestion of Sewage

Solids in sewage contain large amounts of readily available organic material that would produce a rapid growth of microorganisms if treated aerobically. Anaerobic decomposition is able to degrade this organic material while producing much less (approximately one-tenth) biomass than an aerobic treatment process. The principal function of anaerobic digestion is to stabilize insoluble organic matter and to convert as much of these solids as possible to end products such as liquids and gases (including methane) while producing as little residual biomass as possible. It is for this reason that sewage treatment in a conventional septic tank is designed to be an aerobic process. Organic matter treated anaerobically is not broken down to carbon dioxide; final end products are low molecular weight acids and alcohols. These may be further converted anaerobically to methane or, if sent to an environment (such as the leaching field) where aerobic bacteria are present, further broken down to carbon dioxide. Anaerobic digestion of organic matter is also a much slower process than aerobic digestion of organics and where rapid digestion of organic matter is needed an aerobic treatment process must be used.

As discussed above, an anaerobic environment is also necessary for denitrification, as the bacteria which carry out this process require anaerobic conditions to reduce nitrate to nitrogen gas. Many nitrogen-removal technologies are designed to provide an anaerobic treatment chamber as part of the treatment process.

Aerobic Treatment of Sewage

As the name implies, this process utilizes aerobic bacteria to break down sewage. The principal advantage of aerobic sewage treatment is its ability to rapidly and completely digest sewage, reducing BOD to low levels. Most of the alternative treatment technologies discussed in this document utilize some form of aerobic treatment of sewage. This process is used primarily to reduce BOD and, in systems that remove nitrogen, to nitrify the waste so that it can later be denitrified. Because the BOD in raw sewage is usually high, and available oxygen is rapidly consumed by the sewage, most aerobic treatment units are designed to supply supplemental oxygen to the sewage to keep the treatment process aerobic. Some units, such as the JET Aerobic system, use **extended aeration** to more completely digest the sewage solids. Most aerobic treatment units provide some type of artificial medium as a surface on which the sewage- digesting bacteria can grow. A variety of basic designs can be used for this purpose.

Attached culture systems are designed so that wastewater flows over microbial films attached to surfaces in the treatment unit. The surface area for growth of the biofilm is increased by placing some type of artificial media, such as foam cubes or various convoluted plastic shapes with high surface area, in the treatment chamber. This artificial media may sit in the treatment chamber with the effluent circulating through it, usually with supplemental air supplied so that treatment remains aerobic. This is the principal used by the **JET Aerobic** and **FAST** systems. Or, the media may be located outside the treatment chamber and wastewater is passed over the biofilm in intermittent doses. These designs are known as **trickle filters** and are one of the most common types of on-site treatment unit using attached cultures. Some technologies which employ trickle filters, and which are discussed in more detail later, include the **Bioclere**, **Orenco trickle filter**, and the **Waterloo biofilter**. Intermittent and recirculating sand filters, while located in separate chambers, can also be considered a form of trickle filter where sand is used as the media for bacterial growth. Because attached culture systems are generally aerobic, a complex community of microorganisms, including aerobic bacteria, fungi, protozoa, and rotifers, develops. These systems are capable of efficient removal of BOD. Being aerobic THEY WILL SUPPORT THE GROWTH OF NITRIFYING BACTERIA AND CAN BE USED TO NITRIFY WASTEWATER, THE FIRST STEP IN NITROGEN REMOVAL.

Other aerobic systems utilize **suspended culture** of microorganisms to aerobically treat the sewage. This type of treatment assumes that a resident population of bacteria are present in the solids and sludge in the treatment unit; vigorous mixing of the sewage in the treatment compartment causes these bacteria to stay in suspension where they can aerobically digest the sewage. This principle is used by the **Cromaglass** and **Amphidrome** units as part of part of the batch reactor treatment process. It is also used in many large municipal sewage treatment plants.

The **activated sludge** process is similar to suspended culture in that it also utilizes the resident population of bacteria in the solids and sludge in the treatment unit, again, usually by mixing of the sewage so that the bacteria are kept in suspension. In the activated sludge process, however, there are usually periods where mixing ceases, and the solids are allowed to settle. It is then assumed that the sludge will become anaerobic and the anaerobic bacteria in the sludge will denitrify the waste. This is the principle used by **batch reactors.** As the name implies, batch reactors treat sewage in batches. A batch of sewage is allowed to settle so that solids are removed; the batch of sewage is then aerated and mixed and then allowed to settle for a period of anaerobic treatment (this process may be repeated several times on the same batch). When treatment is complete, the finished batch of sewage is pumped out and the next batch enters the unit to begin treatment. The **Cromaglass** and **Amphidrome** systems are examples of batch reactors.

References

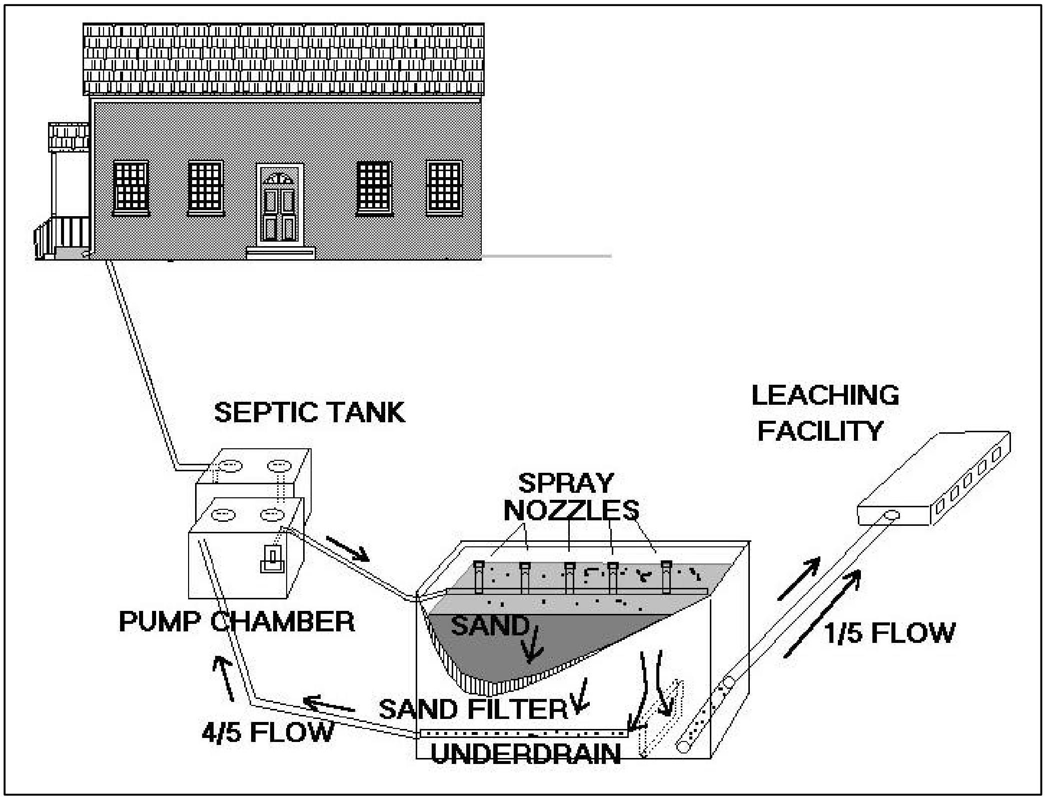
Grady, C.P. Leslie and Henry C. Lim, 1980. *Biological Wastewater Treatment*. Marcel Decker, Inc., N.Y

Peavey, Howard S., Donald R. Rowe, and George Tchobanoglous, 1985. *Environmental Engineering*, McGraw Hill Inc., N.Y.

Recirculating Sand Filters (RSF)

(from ISSUE 5 and Fact Sheet on RSFs)

Authors' Note: *There are significant differences between this chapter and the newsletters. The differences reflect what we have learned about the various design features. Accordingly those techniques and design features that we found do not work, have not been included in this document.*



Recirculating sand filters (RSFs) are perhaps the most common non-proprietary technology in use in Massachusetts as of this writing. In Barnstable County, a few earlier installations were supported through grant moneys in an effort to introduce RSFs again into Massachusetts (the recirculating sand filter or RSF was initially developed in Massachusetts in the earlier 1900s) for the purpose of reducing nitrogen discharge from onsite systems. The first recirculating sand filters in Massachusetts to be monitored extensively were installed in Gloucester. These system installations attempted to demonstrate that overall wastewater management goals of that city could be met by employing advanced onsite treatment. Later installations in the Buzzards Bay watershed (one system in Fairhaven and one in Bourne) focused on the nitrogen removing capability of recirculating sand filters. We estimate that, as of this writing, there are still less than twenty installations in southeastern Massachusetts.

Recirculating sand filters come in a variety of sizes and configurations. The general schematic of three systems installed in Barnstable County is illustrated above, however this illustration shows only one of many ways to achieve the required recirculation. The system is composed of a standard septic tank, a pump chamber, the sand filter, and a soil absorption system or SAS.

The theory behind the recirculating sand filter is simple. Septic tank effluent is pumped from the pump chamber to the top of the sand filter. As the effluent passes through the sand filter, the ammonium-nitrogen is converted to nitrate-nitrogen in a sequence of steps that occur in the presence of air and two genera of bacteria. The first bacterium called *Nitrosomonas* converts ammonium or NH_4^+ to nitrite or $NO2^-$ and the second bacterium, *Nitrobacter*, converts $NO2^-$ to nitrate or $NO3^-$. Following the conversion of ammonium to nitrate in the sand filter, a portion of the effluent is piped back to the pump chamber or the septic tank, while a portion of the effluent passes on to the leachfield. The nitrate contained in the portion that returns to the pump chamber or the septic tank undergoes a further transformation to nitrogen gas (N2). This harmless gas is vented to the atmosphere through the vents in the system. Conditions that must be present for the conversion of nitrate to nitrogen gas to take place are anaerobic conditions and a carbon food source. Both the pump chamber and the septic tank are potential candidates for these conditions, and thus nitrified waste can be returned to either component. It is more common, however, to return nitrified waste from the sand filter to the pump chamber for subsequent denitrification in order to minimize the disruption in the septic tank and promote its function as a primary anaerobic digestion unit in the system.

First Stop - The Septic Tank

Perhaps the most familiar component of the system is the septic tank. The recirculating sand filter, as with most on-site wastewater treatment, must be preceded by a settling chamber such as a septic tank. The revised Title 5 requires that the tank be a minimum capacity of 1500 gallons . For this and other requirements for septic tanks refer to Section 15.223 of the new code. As with all systems having a pump chamber following a septic tank, it is recommended that an effluent filter be installed at the discharge end of the septic tank. This will minimize solids passing through to the leachfield or fouling the pump. As of this writing, there are three effluent filters approved for use in Massachusetts; they are the subject of another chapter in this book.

The Pump Chamber

Following the septic tank, the effluent passes by gravity into a pump chamber. In the recirculating sand filter design shown, the pump chamber serves a dual purpose. First, as a pump chamber, it stores the mixture of septic tank effluent and sand-filter return until it is pumped up to the top of the sand filter. Secondly, facultative anaerobic bacteria located in the pump chamber act on the nitrate in the waste returning from the sand filter to convert it to nitrogen gas. Some designs you may see have a separate chamber, prior to the pump chamber, for this denitrification step. Also, in some proprietary nitrogen removal systems, return effluent from a trickling sand or other filter is returned to the septic tank. The variety of designs are outside the scope of this summary, however you should be aware that there is a wide variety of designs.

Although regular cylindrical or box-shaped pump chambers can be used, you might consider the use of a 1,000 gallon septic tank as a pump chamber. This allows for more than adequate storage volume, and these tanks are readily available at costs comparable to a cylindrical pump chamber. The volume of the chamber should be at least 150% of the design flow for the house. The most important characteristic of the pump chamber is that it be watertight. You might also consider, at least at the pump end of the tank, having a 30-inch manhole for easy access to the pump and wiring. The most important consideration for the pump chamber is that the contents be minimally disturbed or agitated (so that it remains anaerobic). The best arrangement is that return lines from the sand filter and effluent from the septic tank enter the pump chamber enter through sanitary tees that extend below the liquid level. These effluents should enter at the opposite end from the pump that discharges to the sand filter. Allowing for maximum storage volume and installing baffles in the pump chamber are also preferable to encourage anaerobic conditions and longer residence times.

The Sand Filter

The sand filter itself can be constructed a number of ways. In Barnstable County, at least three single family designs have incorporated the bottom half of a 2,000 gallon septic tank with an additional shim to increase the volume and contain the filter media. In Orleans, F.L. Quinn, Inc. used an impervious liner within a constructed wooden box to contain the filter media as part of a RSF "kit" distributed by Orenco Systems® Inc. 814 Airway Avenue, Sutherlin, Oregon 97479-9012. The liner poses somewhat of a problem in sandy soils, since it is difficult to keep the box shape of the filter while backfilling and filling the filter with media, unless a wooden box is constructed to support the liner. The box can deteriorate over time, leaving the liner intact, without affecting the filter. In above-grade filters, timber walls should probably be constructed with treated wood, since they must remain structurally sound for the life of the system.

Distribution of Effluent to the Sand Filter

From the pump chamber, effluent is pressure distributed to the top of the sand filter box. This portion of the system accounts for the majority of removal for Biological Oxygen Demand (BOD) and Total Suspended Solids (TSS). The sand filter box itself, as previously stated, can be made from a variety of materials from concrete to wood with an impervious liner. It must be constructed to allow air passage to the top of the filter. It must also allow for the distribution of effluent to the top of the sand filter bed. Distribution to the top of the sand filter can occur in a variety of ways. If there is a structure or top over the filter, the effluent can be sprayed directly on top of the sand surface. Below are illustrations of two different distribution means where the effluent is sprayed on top of the filter bed. Effluent is distributed from a single line of spray nozzles. The spray of effluent goes upward/outward through slots cut on either side of a 1-inch riser pipe. Another design using splash blocks on top of the media bed referenced in an earlier fact sheet, is not recommended due to the difficulty in obtaining even distribution across the media. An installation of a recirculating sand filter in Wellfleet (Figure 2) used still another means to distribute the effluent onto the sand filter bed. That system employs a series of 15 riser pipes spraying effluent upward. The spray from the risers is deflected downward by half-round 8-inch diameter PVC pipe that covers three spray nozzles each. This system of distribution has an advantage of distributing the effluent more evenly over the media, a highly desired objective to obtain optimum treatment. A similar arrangement, simply using a pressure manifold with 3/8 inch holes oriented to spray upward against a concave shield was installed to serve three cottages in Wellfleet.

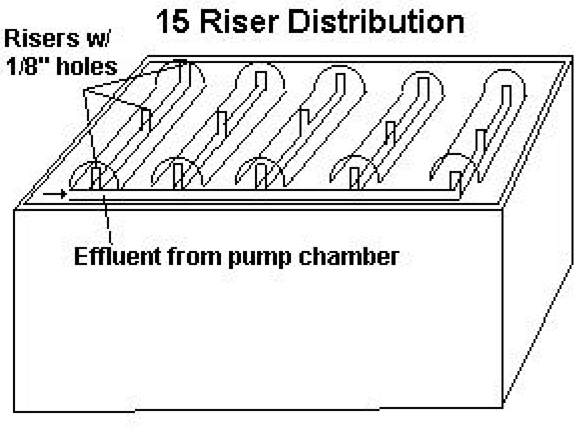


Figure 2. Distribution system currently used in RSF in Wellfleet. Note that a modification of this system using upward oriented discharge holes instead of pipe risers has also been employed successfully.

The two distribution systems illustrated assume that there is a protective cover over the top of the filter bed to prevent uncontrolled aerosolizing and dispersal of the effluent. This technique allows for easy access to the media for servicing by simply lifting the entire cover or portions of it. These accessible-type designs have the advantage of being easier to monitor and gauge the condition of the filter media and service it, should it be needed. The disadvantages to this open-type design include slight to moderate odor problems, particularly if the filter is located near the house.

In the open type design, a wooden top is most commonly used for protection and aesthetics. In summer of 1996, a different type of design with no structural cover was installed in Orleans. In this design, effluent is distributed with a system of pressure laterals to the top of the sand filter, however, peastone is used to cover the entire distribution system. A layer of bark mulch on top of the peastone totally conceals the distribution network. In the Orleans system, the final elevation of the top of the sand filter is nearly at grade, so the entire system is rather inconspicuous. The illustration below (Figure 3) illustrates the distribution piping system to the top of the open-top system in Orleans. Similar "covered" designs have been installed in Gloucester. One of them appears in the yard to look like raised bed contained by timber walls approximately 30 " high. Figure 4 shows a picture of a RSF distribution system by Orenco Systems® prior to covering with peastone and bark mulch.

The dosing schedule of effluent to the RSF is also an important design feature. In general, many and small applications of effluent to the top of the sand filter will result in a better chance for waste nitrification (the important first conversion of ammonium to nitrate). Accordingly, the sand filter pump must be activated by a timer. A preferred dosing schedule is 3-5 minutes on (when the filter receives fresh effluent from the pump chamber), 25-27 minutes off (when the RSF is draining and resting). To achieve the proper recirculation rate of 3:1 to 5:1, a designer should size the pump to deliver three to five times the volume of wastewater generated by the house in equal doses over 48 dosing periods per day. For example, to achieve a 5:1 recirculation rate for a three bedroom home (330 gpd), approximately 1650 gallons of effluent must be distributed to the sand filter over 24 h in 48 equal doses. This equates to just over 34 gallons per dose. For this application, a small pump can be used to deliver 11 gallons/minute over 3 minutes. A note worth mentioning here is that earlier experiments by the Barnstable County Department of Health and the Environment tried using a "demand" rather than timed dose. Under these earlier experiments, demand from the house (approximately 20 gallons) caused 100 gallons or so to be pumped to the top of the filter. 80 or so gallons returned to the pump chamber and 20 discharged to the SAS. This eliminated the need for timers. However, we found that, only if the house has a more evenly spaced flow pattern, will this system work reasonably well. As you will see in the section below, we achieved good results from one system operated in such a fashion, and poor results in another, where the majority of flow was to the system in a very short period of time.

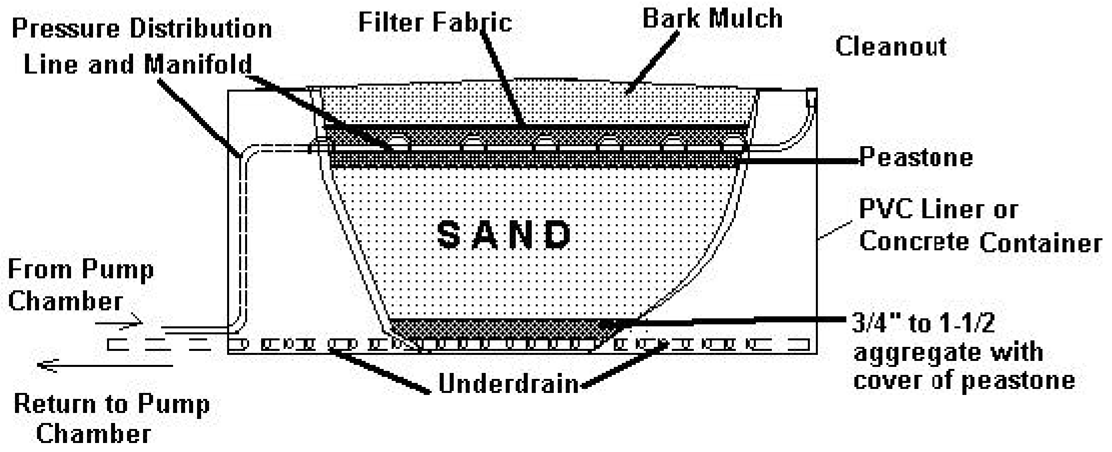


Figure 3. (ABOVE) Schemata of a RSF with no exposed sand surface. The final grade may be at or above existing and surrounding grade. If above grade, the containing liner is supported by a concrete or timber wall.

Specifications for the sand filter media are given in a guidance document issued by DEP. In essence, the sand must have an effective size of 1-2 mm, have a uniformity coefficient of less than or equal to 3.0, and exhibit little fine material (less than 1% by weight shall pass though a # 200 sieve). One of the two recirculating sand filters installed in Barnstable County using native sand, near the tolerances of that specified in the guidance document did experience filter clogging after nine months. The situations were easily remedied, however, since the clogged system was an open type design, and simple raking of the media restored its hydraulic function. We highly recommend that this detail of the system receive the highest level of scrutiny. One source for sand, that has been used in at least four sand filters in southeastern Massachusetts is Holliston Sand and Gravel in Slatersville, Rhode Island (Phone 401-766-5010), however, there are likely many such places to obtain the sand in Massachusetts. An important thing to remember is that deviating from the recommended specifications of the sand must be avoided, if you don't want that midnight call from a homeowner. A final note on media. Recently, while cruising the web, I visited the site of David Venhuizen (e-mail - waterguy@ix.netcom.com). The site contains many design features of recirculating sand filters, and many experiences he has had. David is a regulator in Minnesota and has some opinions on the benefits of RSFs. David feels that the media size has very little effect on treatment, and that peastone works as well as 1-2 mm sand. The advantage to larger diameter media is lower maintenance problems. A review of the literature suggests that this is likely true, as long as frequent small doses of effluent are sent to the sand filter.

Figure 4. Pressure distribution system of a RSF in Orleans, Ma. prior to the installation of protective caps for the spray orifices, peastone, filter fabric, and a top coating of bark mulch. The finished sand filter is only slightly above the surrounding grade.

Achieving Recirculation

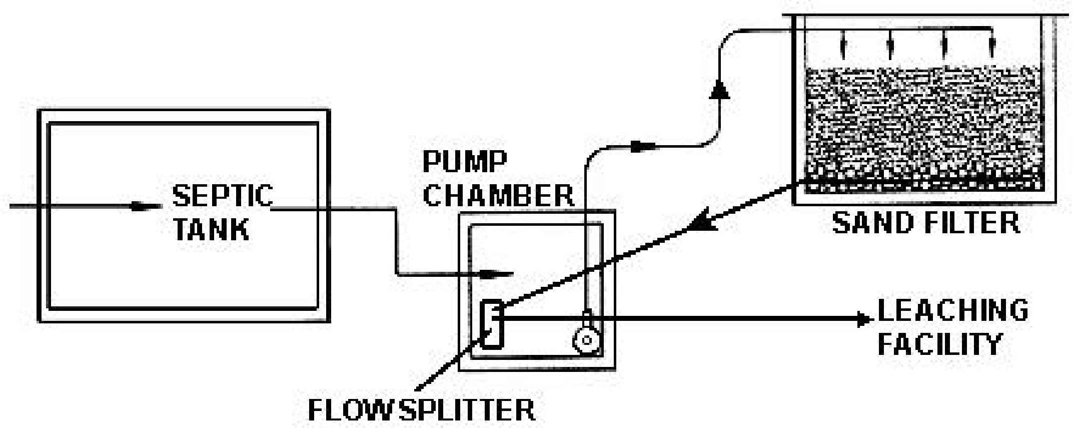
Perhaps the widest variation one can find in RSFs is the method of splitting the flow from the sand filter to achieve the desired recirculation. Three methods will be discussed below:

- splitting the flow in the sand filter itself;
- using a redirecting valve (ball valve, "Mickey mouse" valve or the like) inside the pump chamber, and;
- using a splitter valve outside of the pump chamber

Splitting the flow within the sand filter

In our first illustration, we show that flow from the sand filter is split in the bottom of the sand filter box. Approximately 80% of what is sprayed on top of the sand filter is returned to the pump chamber for denitrification, while approximately 20 % is released to the SAS. The proportioning of filtrate is set by the location of a dam constructed on the bottom of the sand filter that directs the larger portion of the effluent back to the pump chamber, while allowing the smaller portion to discharge to the SAS. This is perhaps the simplest design, however it is crucial in this design to uniformly distribute effluent to the top of the sand filter. For instance, if the effluent was all distributed over the return portion of filter, effluent would never discharge to the SAS. Conversely, if the effluent is distributed more over the top of the discharge side of the dam, more discharge to the SAS will occur than is desired.

While the advantage of this type of design is simplicity, as usual simplicity has its cost. Under this design, a portion of effluent is always discharged to the SAS, and chances for further treatment of this effluent in the RSF is lost. In addition, since the dam at the bottom of the system is permanently installed, changing the proportion of return to discharge would extremely difficult. This is a popular design among some regulators, notably Richard Piluk, a County Health Department Official in Ann Arundel County Maryland, who sees this as a low maintenance feature that can still achieve 60+% nitrogen reduction. A note here, however, is worth repeating. The flow to the RSF should be on a timed cycle, ideally with many small doses and long resting periods that will encourage more complete nitrification. As mentioned, our earlier experiments with demand doses gave inconsistent results. Also worth mentioning here is the fact that, under this arrangement, when there is no water use in the residence (such as through the night or when a vacation is taken) eventually the low-water shutoff of the pump chamber will stop any distribution of effluent to the sand filter. While some researchers feel that this might be an advantage, many feel that it will result in the sand filter becoming anoxic. In any event, when using the bottom of the sand filter to split the flow, it is desirable to adjust the pump cycles so as to minimize the inactive periods where the filter will not be fed effluent.



Splitting the flow inside the pump chamber

Another way to achieve the desired recirculation in an RSF system is to collect all of the filtrate from the sand filter and split (a portion going each to the pump chamber and the SAS) somewhere else in the system. In the majority of systems installed in Massachusetts using this technique the flow is split within the pump chamber. Simply put, all of the effluent from the RSF is returned by gravity to the pump chamber, where it either empties back into the pump chamber (for denitrification) or passes through the pump chamber into the SAS. This feat is achieved by use of a device variously called a ball valve, buoyant ball valve, or "Mickey mouse" valve. The concept is illustrated below. The control of flow (either to the pump chamber or through to the SAS) is dependent on the volume of liquid in the pump chamber.

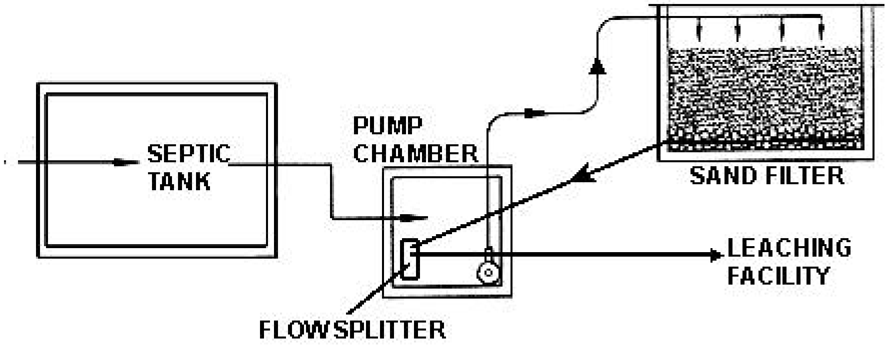


Figure 6. Schemata of a RSF using a buoyant ball valve for recirculation control.

The buoyant ball valve illustrated here (Figs. 7a and 7b) consists of an inlet from the sand filter, an outlet to the leach field, a downward outlet to the pump chamber, and a

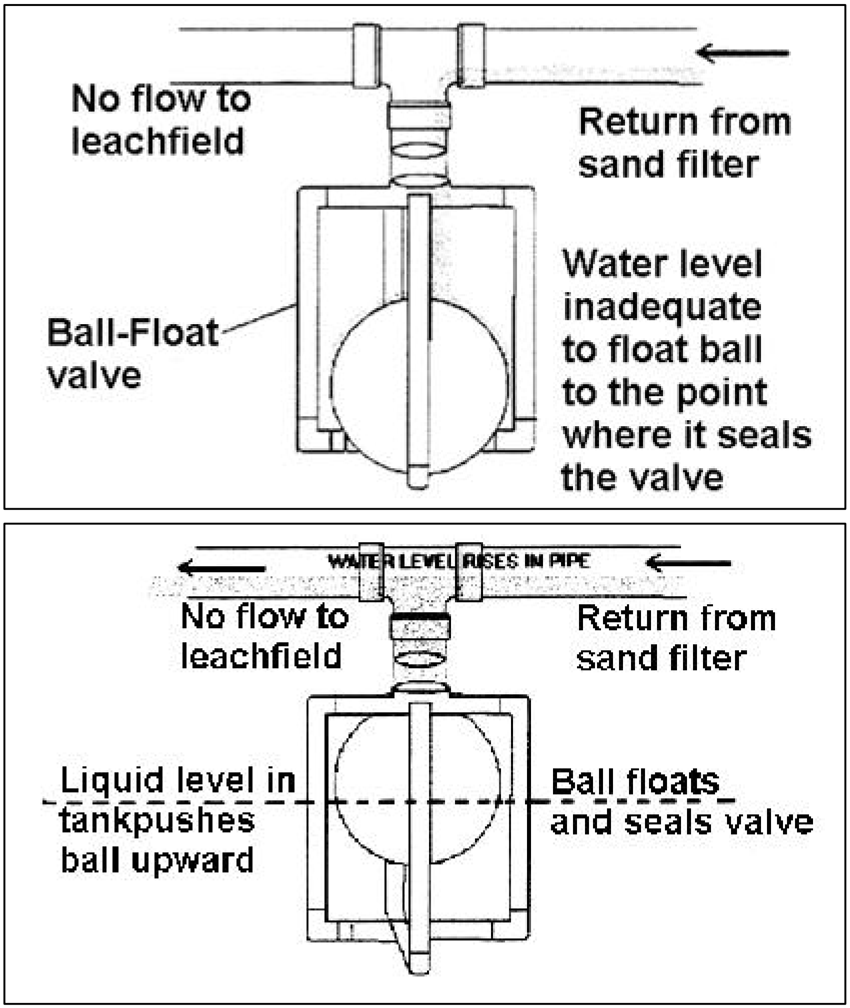


Figure 7a) all flow returning from the sand filter is returned to the pump chamber where denitrification takes place. B) liquid level in the pump chamber rises to the point where the buoyant ball rises and seals the drainage port into the pump chamber and causes effluent to pass through to the leaching facility.

buoyant ball which seals the downward outlet. Sand filter-treated effluent returns to the pump chamber via the ball valve. As the level of liquid in the pump chamber rises, the ball rises and exerts enough pressure to make a firm seal on the downward outlet. When the ball seals the downward outlet the remainder of the effluent passes to the leach facility. Use of a buoyant ball valve has the advantage of being reliable, inexpensive, and simple to maintain. More importantly, the buoyant ball valve allows recirculation of pump chamber contents at times of no water usage in the building without voiding any volume to the leaching field. Theoretically, this allows for better treatment of the waste during times of lower flow. The buoyant ball valve only discharges to the field if there is adequate volume in the pump chamber.

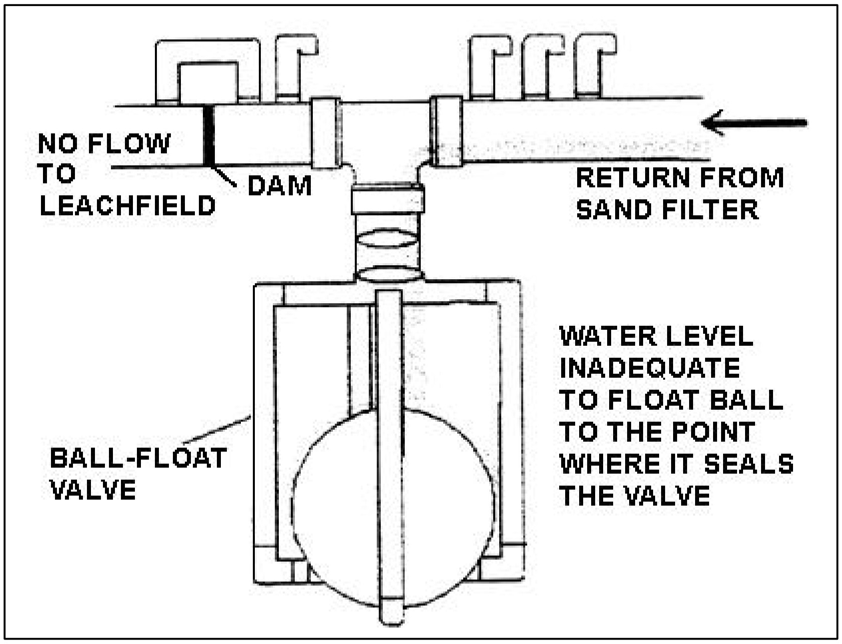
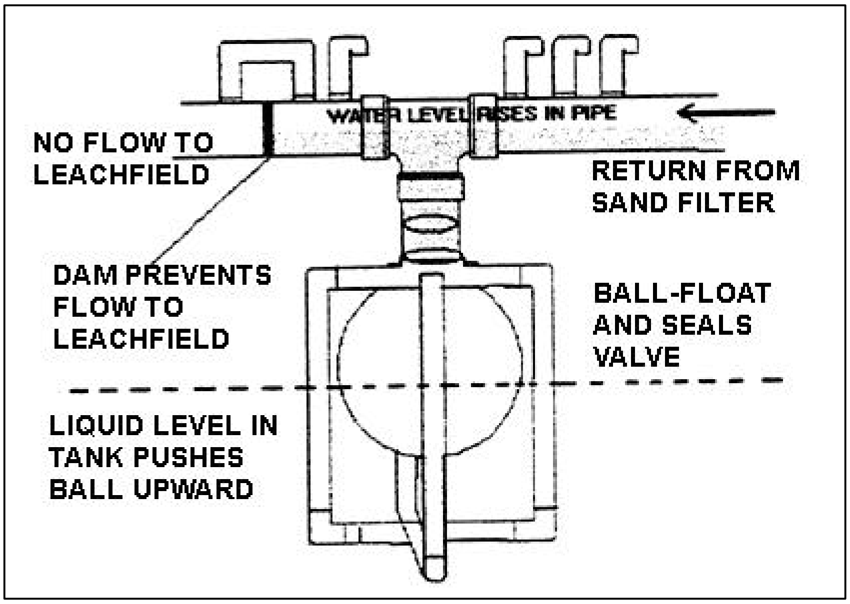
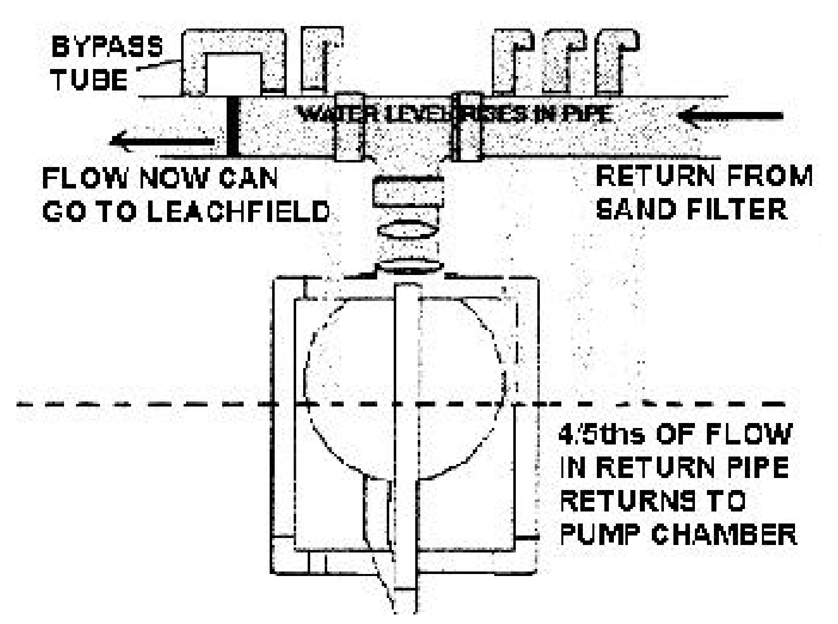


Figure 8. a) all flow returning from the sand filter is returned to the pump chamber where denitrification takes place. **b-c)** liquid level in the pump chamber rises to the point where the buoyant ball rises and seats seals the drainage port into the pump chamber and causes effluent to pass through the five "fingers", one of which connects with the pipe exiting to the leachfield, and the remaining four spill back into the pump chamber. **d)** picture of the valve device as installed in a RSF in Orleans.



An attempt to improve treatment even more was developed and is in use in the Orleans RSF. This addition to the standard buoyant ball valve prohibits the direct discharge of all of the returning effluent from the sand filter, even when the buoyant ball valve seals the downward path to the pump chamber. It does this by using the scheme shown below in Figure 8.



Splitting the flow outside of the pump chamber using a splitter valve

The final way we will discuss splitting the flow returning from the recirculating sand filter is by use of a splitter valve located outside of the pump chamber. Various valves and devices have been suggested for this method, however, we have not seen any, as of yet, used in Massachusetts. The simplest splitting device is a distribution box with multiple exit ports. If four exits are present, three may be piped to return to the pump chamber and one to the SAS. By using adjustable inverts in the distribution box, a wide adjustment of forward (to the SAS) to return (to the pump chamber) flow can be achieved (Figure 9). Since we have not seen any of these in use yet, we can not comment on their merit.

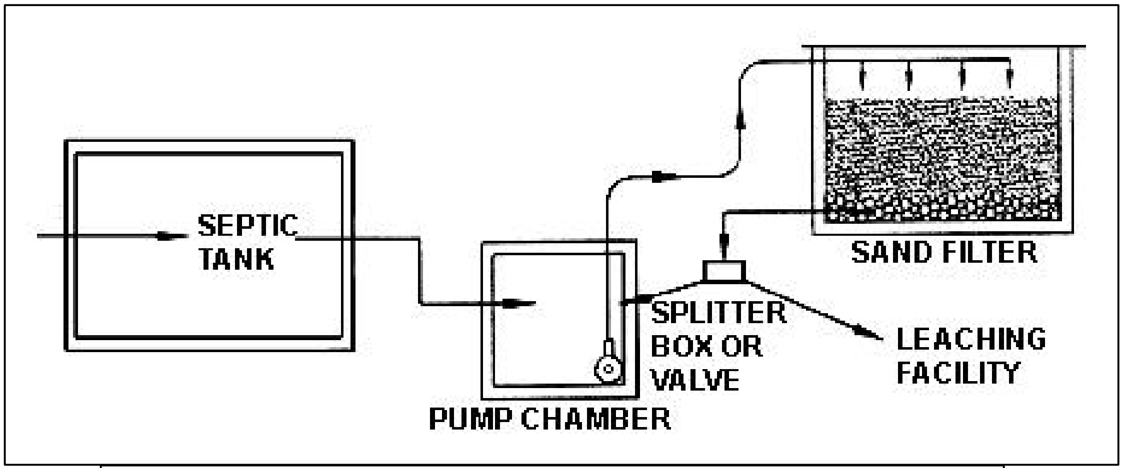


Figure 9. Schemata of a recirculation strategy using a splitter box or valve outside the pump chamber.

A FINAL WORD ABOUT RSF DESIGN

Before designing a RSF, you should consult the DEP Guidance Document regarding various aspects of the design. Some of the lessons we have learned have already been stated in this and the following text where we give the results from BCHED's first installation. In general, designers should make sure that all parts of the RSF are easily serviceable.

One frequently asked question relates to how long the filter media can go without replacement.. While the media never really has to be replaced, the filter may eventually clog due to the unavoidable buildup of suspended solids which will not break down. The service interval will depend highly on the amount to TSS allowed on top of the filter. Accordingly, designers should incorporate effluent filters in all designs. When the unit must be serviced, the sand may either be replaced outright or cleaned and replaced. Richard Piluk, that County Health Department Official in Ann Arundel County Maryland, makes allowances for shutting the underdrain from his filter off. He then floods the filter with water and blows compressed air into the filter bed. As the water boils to the top, carrying the collected solids, he pumps them off and disposes of them similar to septage.

This non-proprietary technology can be configured many different ways and still comply with the required criteria. What is important for the designer is that you think ahead to the time when this pump or that float valve malfunctions. Safeguards and alarms are the first line of defense against system failure.

On the following pages are some of the results from a year's worth of sampling at an RSF we installed in Bourne. As you will see, some of the results are quite variable, particularly in regard to nitrogen removal. We feel that the reason for this is the fact that for the first year of operation, we operated this, and one other system, on a demand cycle. In the coming year, we will be operating our systems closer to the state guideline mode of operation and expect better removal efficiencies. At the time of installation, no official state guidelines were available.

A YEAR AT PAUL'S PLACE - A RECIRCULATING SAND FILTER'S PERFORMANCE AFTER ONE YEAR

(from Issue 5)

As many of you may know, our Department assisted in installing and monitoring a recirculating sand filter at the house of Paul Montague, who now serves as the Shellfish Constable in Falmouth. Paul has a two-bedroom home on the water in Bourne, and in 1994 decided to upgrade his cesspools to at least a Title 5. With some funding for design through the Buzzards Bay Project, Paul and his wife Edna bit the bullet and installed a recirculating sand filter. The system consists of a 1000-gallon septic tank, a 1000 gallon watertight pump chamber, a 2000 gallon recirculating sand filter and a leaching facility comprised of two leaching chambers surrounded by three feet of stone. Since July, 1994 on at least 20 occasions, we have been monitoring untreated effluent from the septic tank, water in the anaerobic pump chamber, sand filter effluent and groundwater from a well and suction lysimeters directly below the leachfield. A schematic of the sy~~stem is presented in figure 1 at the beginning of this chapt~~er.

RESULTS

Removal of fecal coliform exceeded 95% on all but five sampling dates (Figure 10). Fecal coliform densities in septic tank effluent ranged from 10,000/100 ml to 4,300,000/100 ml. Effluent from the sand filter ranged from 50-50,000 fecal coliform/100 ml. Occasionally, there is significant passage of fecal coliform through the sand filter, however the monitoring well placed directly beneath the leaching facility had fecal coliform levels reaching only 0-100 FC/100 ml indicating that the soil beneath the flow diffusors is acting to efficiently filter fecal coliform prior to reaching the groundwater.

Reduction in Biological Oxygen Demand (BOD) consistently exceeds 90% after treatment by the sand filter, and ranges from 97-98% efficiency when the water temperatures exceed 10 C (Figure 11). Septic tank BODs ranged from 151-344 mg/l with an average of 223 mg/l. Treatment through the sand filter reduced this to 2.3-18.0 mg/l and averaged 8.8 mg/l. The data show a clear seasonal trend related to water temperature. In March, a clogging layer was observed on the top of the sand filter that appears related to the reduction in BOD removal efficiency. After raking the top of the filter to break up the clogging layer, the filter returned to normal operation and has not clogged since.

Initially, the phosphorus removal from the system looked good (90% removal from July-September, 1994). From February, 1995- early May, the removal efficiency for phosphorus dropped to 30%. Since May, the efficiency has further dropped to 0-15% (Figure 12). We hypothesize that the removal of phosphorus is governed by the chemisorption of phosphorus onto surfaces of iron minerals. In time, it would be expected that adsorption sites would become saturated and soluble phosphorus would pass unattenuated through the filter. In the coming year, we may be experimenting with coating the top of the filter with iron-rich sand to determine whether we can again increase the phosphorus removal capability of the system.

Nitrogen removal efficiency, measured as loss of total dissolved nitrogen (TDN= nitrate + ammonium + dissolved organic nitrogen) has been variable. Average nitrogen loss over the year has been 32% (Table 1). TDN in septic tank effluent averages 70.6 mgN/l and TDN in the sand-filter effluent averages 48.2 mgN/l.

Nitrification (or the conversion of ammonium from the septic tank to nitrate) appears to be complete, even during the winter months when water temperatures were low (Figure 13). Nitrification approaches 100 % when the water temperatures measured at the pump chamber exceed 10C. Despite what the conventional wisdom says about nitrification, it appears that this is not the limiting process in the overall denitrification, even during winter months.

Since nitrification does not appear to be the limiting step in loss of total nitrogen to the system, we can assume that denitrification (the conversion of nitrate to nitrogen gas) is. Denitrification rates do not appear related to temperature since levels are variable throughout the winter months. The availability of carbon (as measured by BOD in the anaerobic pump chamber) similarly does not appear to limit denitrification since levels there range from 8.4-65 mg/l which should be sufficient to support the growth of denitrifying bacteria. Presently, we hypothesize that the higher dissolved oxygen levels in the pump chamber (average 1.5 ppm from December-March), prevalent in colder months may have limited the denitrification step. In the coming months, however, we will be measuring pH and alkalinity in this pump chamber to see if these parameters may be affecting this vital step in the nitrogen-removal process.

TABLE 1.

	TDN Septic Tank Effluent	TDN D-Box finished effluent
mean	70.6	48.1
std deviation	8.28	9.2
n=	21	21

OPERATION

The recirculating sand filter had only few operational problems. During late winter, the surface of the sand filter clogged with a fine organic layer and caused ponding of effluent. The filter resumed normal operation following a raking of the sand filter surface. Based on this experience, we recommend that there be quarterly servicing of the top of the sand filter. It should be visually inspected monthly during winter months. Experience with the sand filter in Fairhaven, however suggests that no clogging would have occurred if more uniform sand was used. In addition to this problem, the opening on the spay nozzles should be periodically inspected for clogging. In our case, leaves inadvertently entered the pump chamber during our sampling and clogged some of the ports.

Figure 10

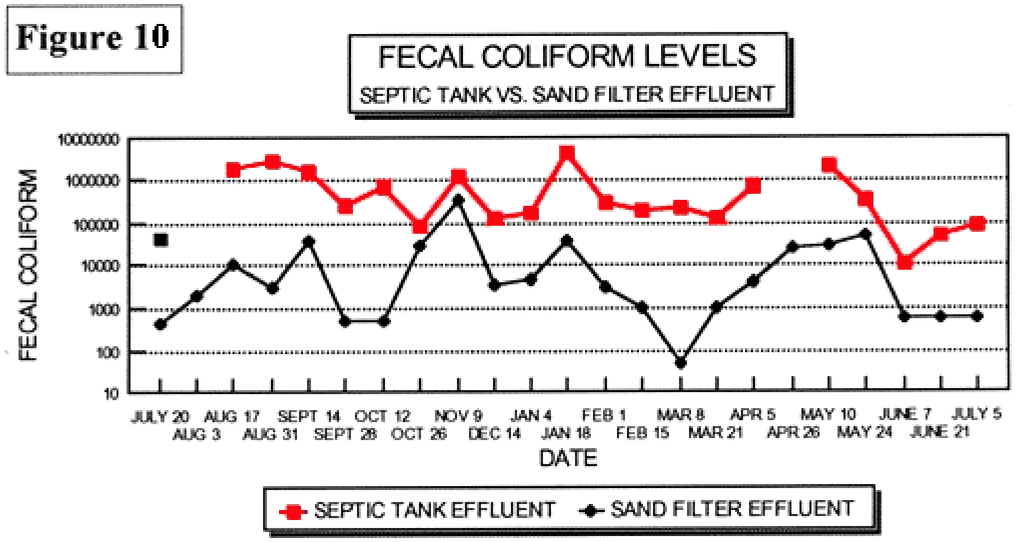


Figure 11

BOD REMOVAL
Septic Tank vs. Sand Filter Effluent

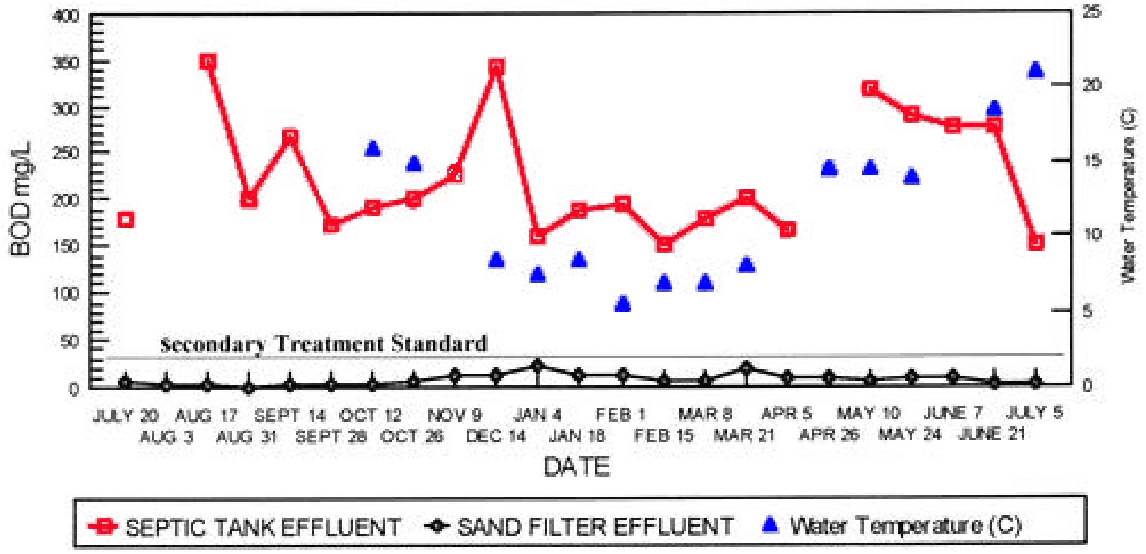


Figure 12

PHOSPHORUS REMOVAL
Septic Tank vs. Sand Filter Effluent

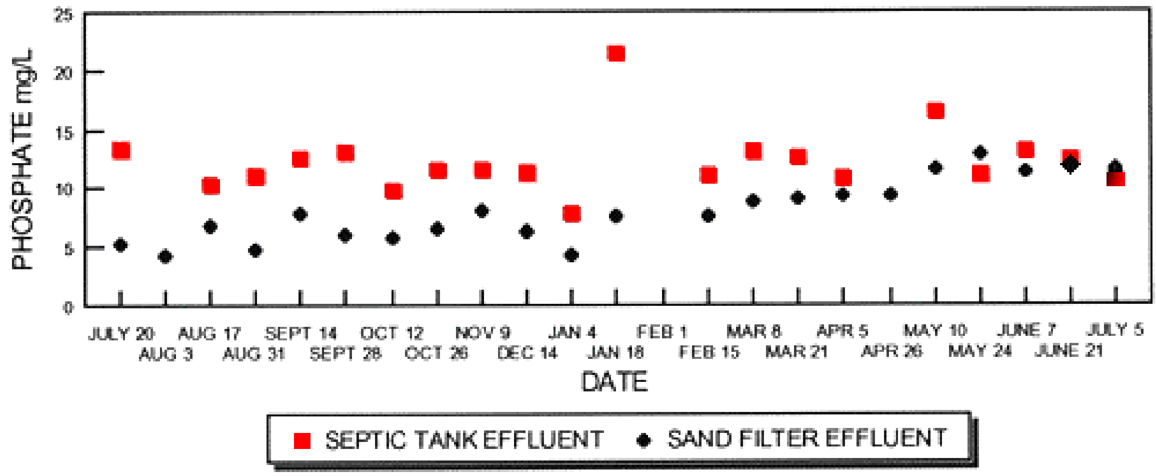
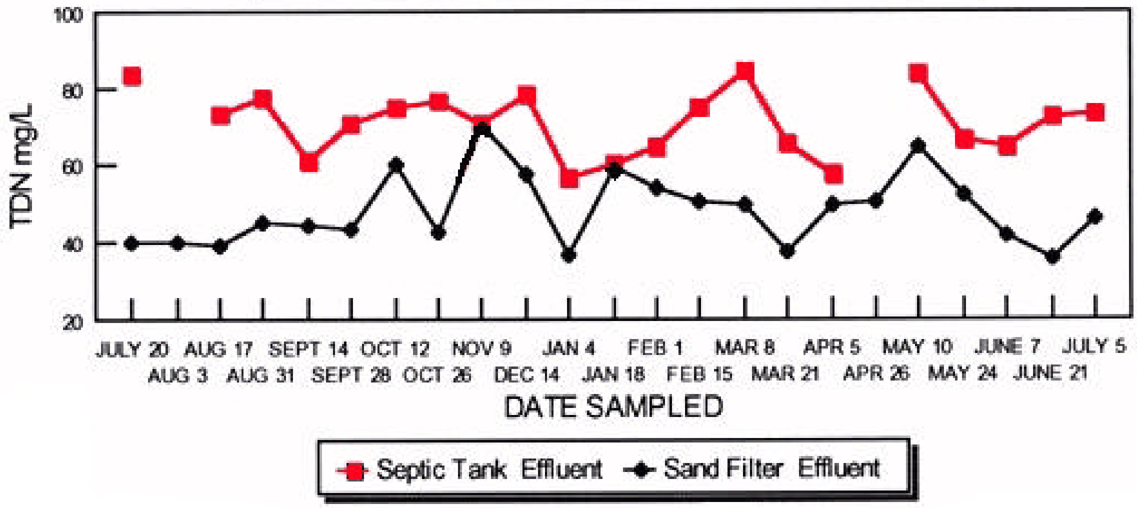


Figure 13

TOTAL DISSOLVED NITROGEN LEVELS
Septic Tank vs. Sand Filter Effluent



SYSTEM UPDATE

This past winter, we have retrofitted the Montague system with a timed dosed arrangement. We will be taking samples over the next year to see whether , in this instance, we increase the performance of the system and decrease both the slight odor and maintenance requirements. The dose setting is 5 minutes on, 25 minutes off - more in accordance with the state guidelines for recirculation rates. In addition, we replaced the distribution system on top of the sand filter with a 4-pipe lateral pressure distribution network that could be covered with peastone. The pressure distribution network was purchased from ORENCO, however, it could have been made from non-propriatary parts quite simply. Another change we made to Paul's system has been the volume of liquid we maintain in the pump chamber. Initially, we only maintained one foot or so of liquid in the pump chamber (which, as you remember serves also as the denitrification chamber). We now understand that maintaining a higher volume in the pump chamber will help stabilize the temperatures in the winter and provide for more anaerobic conditions necessary for denitrification. Dissolved oxygen levels in the pump chamber are more affected by returning sand filter effluent when small volumes are in the pump chamber. Accordingly, and to maintain the required anaerobic conditions in the pump chamber, we decided to maintain larger volumes of liquid. Keep an eye out in future newsletters to get the results of these modifications.

Peat Filter Septic Systems

A peat septic system functions much like a conventional Title 5 septic system with the exception that the wastewater receives treatment by being filtered through 2 to 3 feet of peat before being discharged to the soil for final disposal. Water from the dwelling first flows to a conventional septic tank where solids settle. The clarified effluent then flows, either by gravity or by pump, to the peat filter. The peat acts much like a sponge, absorbing and wicking the effluent in all directions and providing treatment as the wastewater slowly filters through the peat. Eventually the effluent filters to the bottom of the peat where it percolates into the soil for final disposal. Experimental results show that peat filters are capable of very efficient removal of fecal coliform bacteria, biochemical oxygen demand (BOD) and total suspended solids (TSS). They also appear to be capable of a producing a significant loss of total nitrogen in finished effluent.

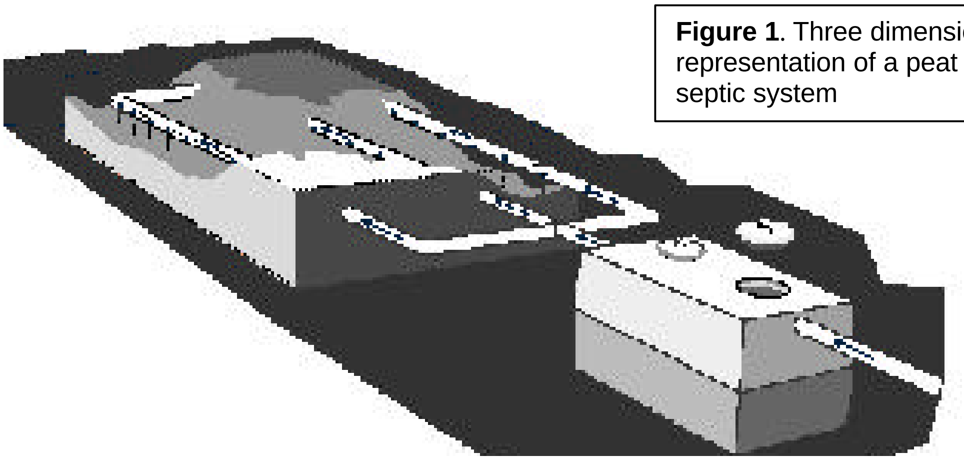


Figure 1. Three dimensional representation of a peat bed septic system

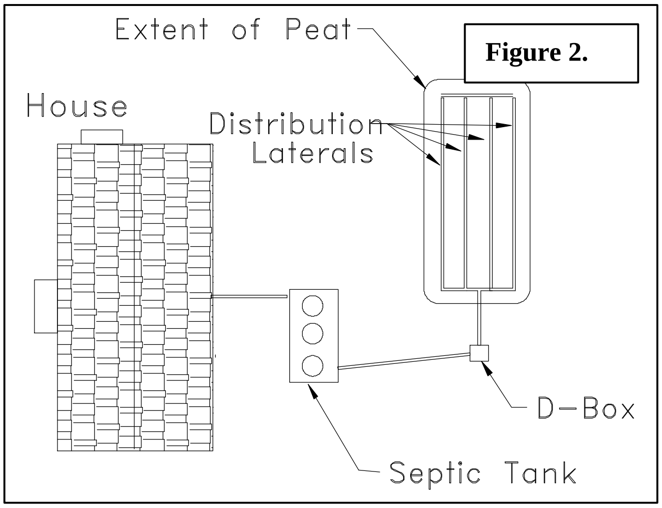
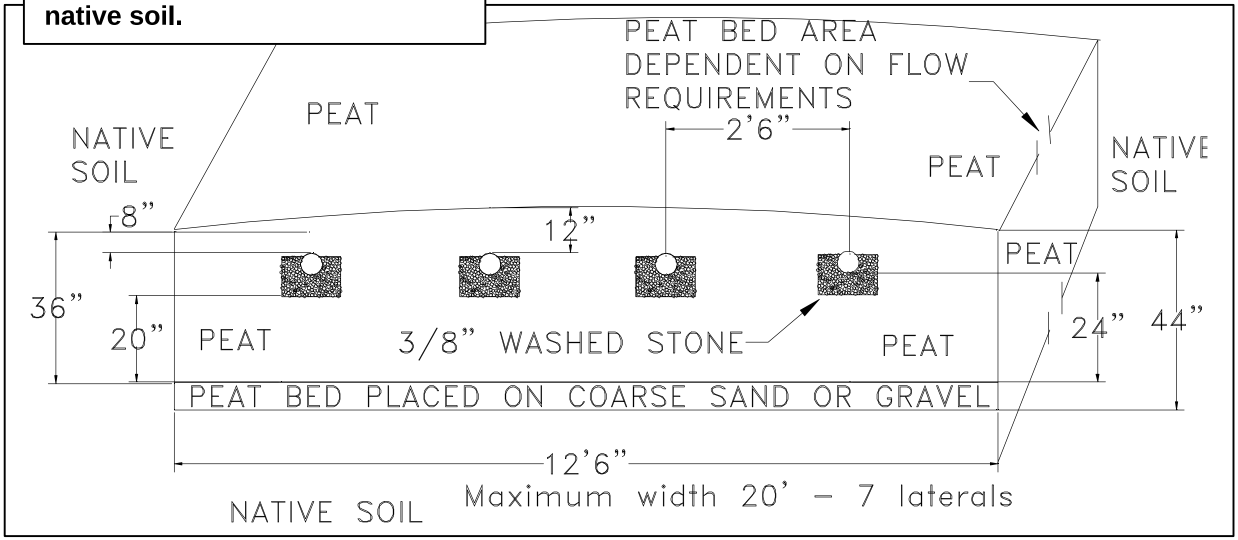


Figure 2.

Several designs of peat filters are available. These range from simple gravity fed systems to more complex modular systems that require pumps and may recirculate effluent to an anaerobic containment vessel such as the septic tank or pump chamber to achieve more efficient nitrogen loss.

The simplest and earliest design for a peat septic system was developed by Dr. Joan Brooks of the University of Maine Department of Civil Engineering in the late 1970s. In the **Brooks design** the peat filter serves as the leaching field. Instead of being laid in a more conventional bed of gravel, the perforated pipe that distributes the effluent is laid in a bed of compacted sphagnum peat (Figure 1, a three-dimensional sketch of system (D-box omitted); Figure 2, typical layout of a simple peat system; Figure 3, cross section schematic of peat bed with piping). The system is passive, with no mechanical parts, and operates in the same way as a conventional Title 5 system. Effluent exits the septic tank, flows by gravity to a distribution box and then through the distribution piping

FIGURE 3 Typical peat bed constructed in excavation in native soil.



to the peat-filled leaching bed. After the effluent filters through the peat it percolates directly into the soil below the peat bed for final disposal. The system is constructed on-site (construction techniques are discussed below) by a local septic installer trained in the proper installation of this type of system.

At least two proprietary, modular peat filter systems are also available. Each module contains pre-compacted peat or peat fiber and piping in a concrete or polyethylene box. The modules are delivered pre-constructed to the site where they are installed with minimal site preparation. Use of a modular filter simplifies system construction and provides quality control by ensuring that the peat used meets designer's specifications and is properly compacted. The modular units can be designed to drain directly to the underlying soil, or can be designed with an underdrain for discharge of the treated effluent to a separate disposal area. These proprietary systems include the **Enviro-pure^{TM} On-site Wastewater Treatment System** (Figure 4), marketed by American Concrete Industries in Maine

ENKADRAIN referenced in the illustration below is a proprietary product that looks like snarled up fishing line with a layer of fabric cloth on one side.

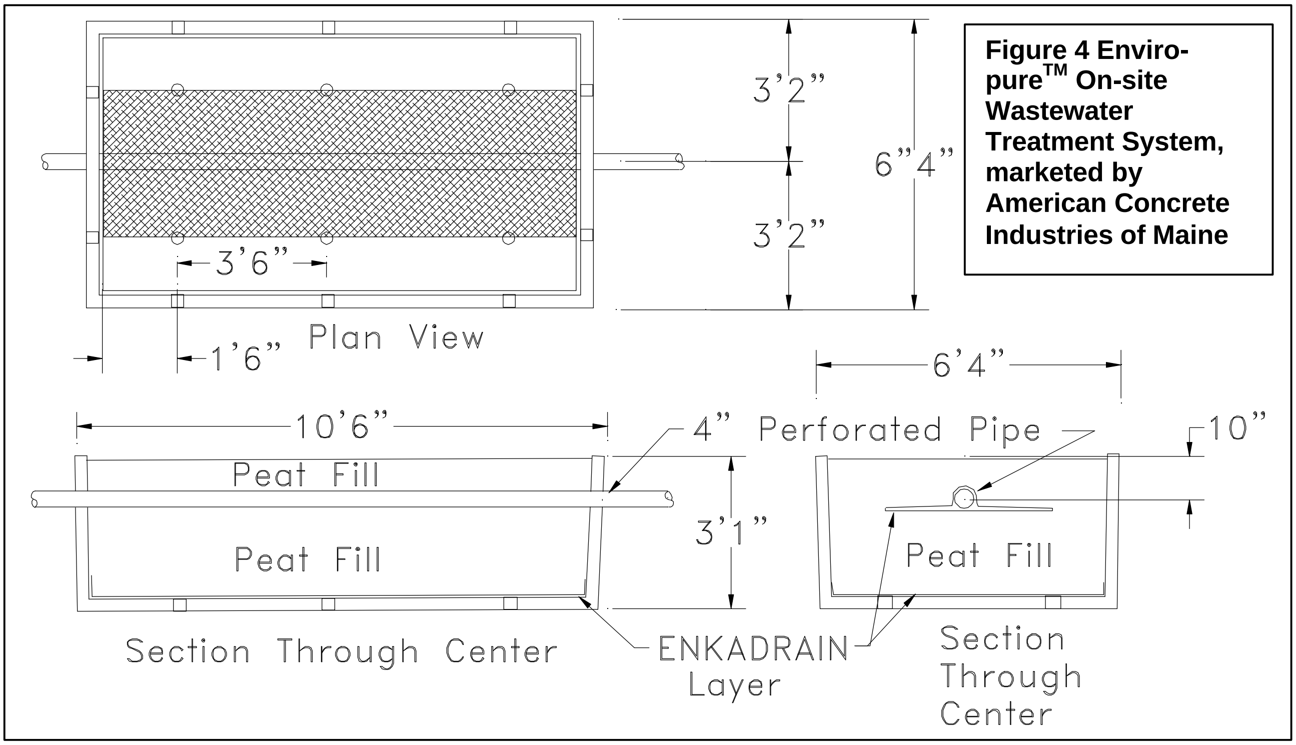


Figure 4 Enviro-pure^{TM} On-site Wastewater Treatment System, marketed by American Concrete Industries of Maine

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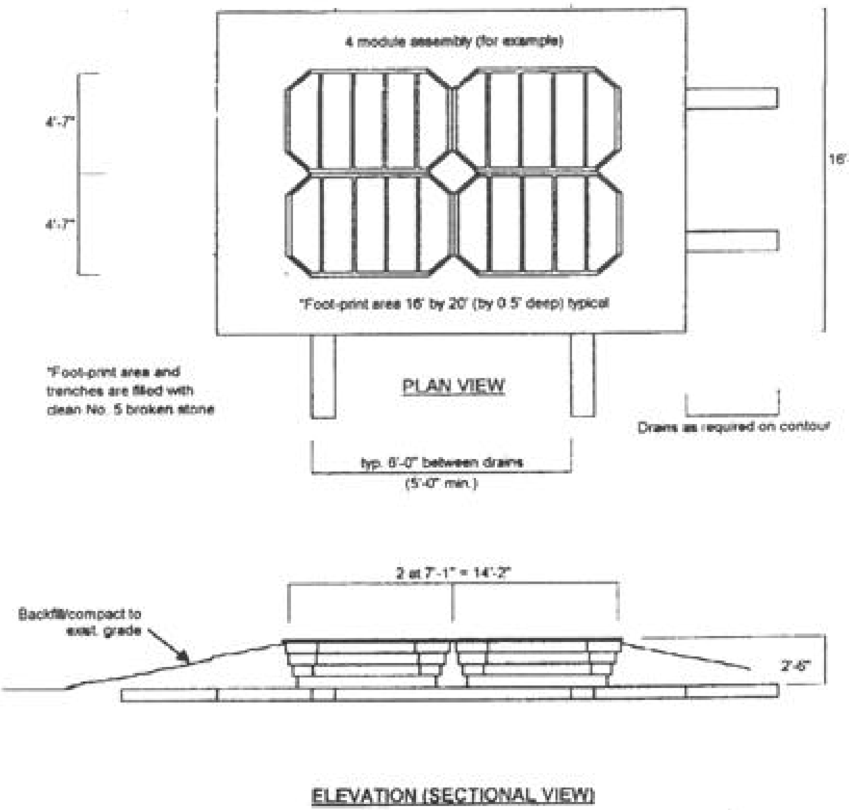
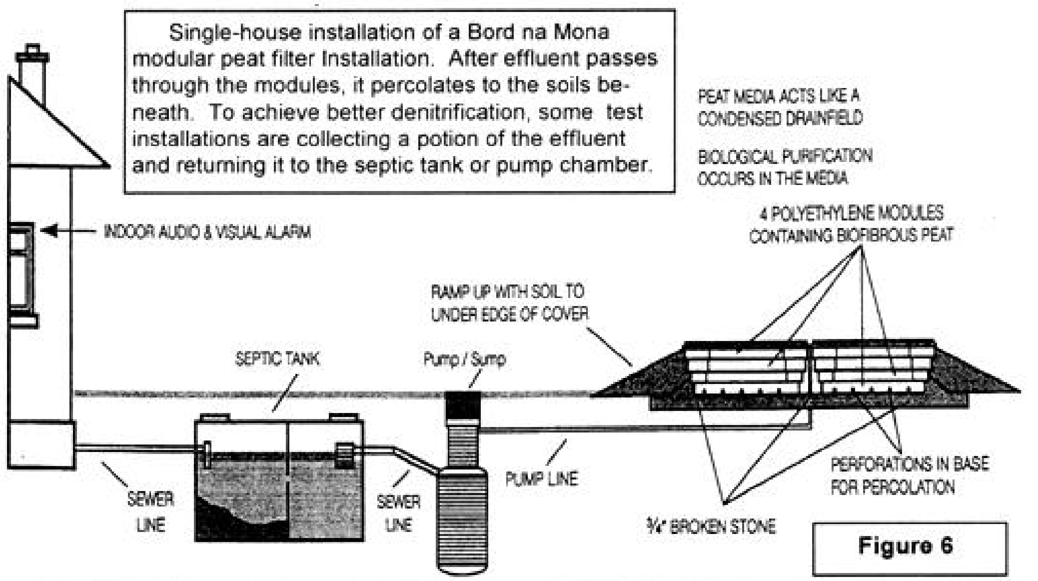
FIGURE 5 Puraflo™ Peat Biofilter developed and marketed by Bord na Mona (illustrations provided by Bord na Mona)





Single-house installation of a Bord na Mona modular peat filter Installation. After effluent passes through the modules, it percolates to the soils beneath. To achieve better denitrification, some test installations are collecting a potion of the effluent and returning it to the septic tank or pump chamber.

Figure 6

Can any type of peat be used?

No! Before you rush to your local garden center with the idea of buying a few bags of peat and building one of these systems yourself, be aware that a very specific type of peat must be used. The peat must be air dried (horticultural peat is usually heat dried which permanently changes the structure and properties of the peat fiber), have a very specific moisture content and degree of decomposition. Peat meeting these specifications is mined from peat bogs specifically for use in peat filter systems.

HOW DOES THE PEAT FILTER TREAT THE EFFLUENT?

Porosity: *the ratio of the volume of interstitial space in a material to the entire volume of the material.*

Peat has a porosity of about 95%, and, consequently, a very high surface area. Peat's surface area is about 200 m^2 per gram of peat!!!!

The peat filter can in some ways be considered to be a fixed film filtration system much like other sewage treatment filters composed of sand or artificial media. Peat, however, has unique chemical, physical and biological properties, all of which contribute to the sewage treatment process. Sewage treatment within the peat filter is accomplished by a combination of physical filtration, chemical adsorption, and biological treatment by microorganisms. Peat fibers are polar, have a high surface area, and a highly porous structure (90-95% ***porosity***). These properties enable the peat bed to hold a large amount of water, much like a sponge. As a result, effluent has a long residence time in the peat. As the wastewater is wicked through the peat it flows in a thin film over the surfaces of the peat fibers. This allows the effluent to become aerated, become exposed to the acidic chemical environment of the peat, and come in close contact with the microbiological community inhabiting the peat. The relatively constant moisture content of the peat filter also enables the survival of the natural microbial population in the peat even when the system is not being actively used. Moisture in the peat also helps keep the temperature of the peat bed relatively constant even when outside air temperatures change. This likely accounts for peat's ability to perform well even in very cold conditions. Solids that are larger than the interstitial channels in the peat are trapped on the peat fibers as the effluent trickles through the peat. This accounts for the very low total suspended solids seen in finished effluent and may account for some removal of BOD as organic particles are trapped for later digestion. The highly polar nature of the peat fibers creates an environment with a high ***cation exchange capacity***. Many wastewater components become chemically adsorbed to the peat fiber surface causing them to be trapped in the peat. Peat's highly porous structure and very high surface area make the peat bed an ideal environment for supporting an aerobic microbiological community that performs biological treatment of the sewage. Within several weeks of use the peat filter is colonized by a range of microorganisms and invertebrates from the septic tank effluent and the surrounding soil. These include bacteria, fungi, protozoa, nematodes, earthworms, rotifers and others. Treatment of the septic tank effluent is performed mainly by acid-tolerant bacteria and fungi living in the peat media. Pathogenic bacteria in the wastewater undergo significant die-off in the peat due to the acidic conditions and predation and competition from the natural microbiological community in the peat. It is also possible that the fungi in the peat produce antibiotics and that the peat itself releases antibiotic and phenolic substances that further act to reduce bacterial numbers.

Cation Exchange Capacity:
the total amount of cations -- positively charged particles -- that a soil can adsorb.

Peat is contains lignin-like substances that are negatively charged. This gives peat a great ability to adsorb positively charged molecules. Peat's high cation exchange capacity means the peat can effectively hold positively charged molecules including ammonium, metals, pesticides, some organic molecules, and possibly viruses.

The mechanism by which nitrogen is removed by passage through the peat is somewhat unclear. It appears that a number of fungi can use organic nitrogen, ammonia, and nitrate directly and reduction in nitrogen may be due in some part to the activity of these fungi. There is some evidence that a significant amount of nitrogen loss may be due to denitrification. For nitrogen removal to occur by denitrification, ammonia (NH_3) and organic nitrogen entering the peat must first be converted to nitrate (NO3-), a process known as **nitrification**. Nitrification is bacterially mediated and requires aerobic conditions. Nitrification is known to occur in peat filters: monitoring results show that most nitrogen entering the peat filter occurs as ammonia while most nitrogen leaving the peat filter is in the form of nitrate. The actual site for the nitrification process in the Brooks design is not known. The low pH of the leachate suggests that the peat bed is not a favorable habitat for nitrifying bacteria. From our research, we theorize that nitrification might occur in the zone immediately surrounding the distribution pipes, where the pH is more favorable to the process. Once nitrogen has been converted to nitrate, **denitrification** (conversion of NO3^{-} to N2 gas) can occur. This process is also bacterially mediated, requires a biodegradable carbon food source for the bacteria, and an anaerobic environment. Peat filter beds can be ideal areas for denitrification. The peat itself contains large amounts of organic carbon. The lower portions of the peat bed may be anaerobic, at least periodically when the bed receives surge loads. Or, possibly, anaerobic microzones are created on the peat fibers -- when bacterial biomass on the peat fiber becomes thick oxygen is not able to penetrate the biomass film, the area at the biomass/media interface becomes anoxic and denitrification can proceed. This allows nitrification and denitrification to occur simultaneously in the peat bed. Some nitrogen loss in the peat may also be due to uptake by plants surrounding, or planted on top of, the peat. A recent literature review (*Water Research* , vol. 28 no. 6, 1994) suggests that up to half of the nitrogen removal observed may occur via this route.

WASTEWATER QUALITY

All peat filters tested consistently remove greater than 90% of fecal coliform bacteria and many remove greater than 99%. The Puraflo 1-pass filters seem generally capable of a 1-log reduction in bacterial numbers. The two Brooks peat beds installed by this department show an average 4-log reduction in bacterial numbers. This is probably because the Brooks design uses a different type of peat and because the peat filter is loaded with wastewater at a significantly lower dosing rate. Reductions in biochemical oxygen demand (BOD) range from 80% to almost 100%. All the systems tested, with one exception, have been able to produce a finished effluent with average BOD below 30 mg/L, the secondary treatment standard. The one exception is the peat system installed in Wellfleet by this department, which showed an average BOD in finished effluent of 45 mg/L; however, BOD entering the peat filter averaged 623 mg/L (2-3 times higher than typical residential sewage) and BOD reduction for this system averaged 93%. Total suspended solids (TSS) are also reduced significantly. Puraflo reports an average 91% reduction in TSS at several installations in Alabama and an 85% reduction in TSS at a residential system in Maryland. This department's results with the two peat systems installed in Eastham and Wellfleet show 70 and 92% removal of TSS by the peat filter.

The ability of peat filters to remove nitrogen varies widely from system to system ranging from about 30% to 65% removal of total nitrogen. The reason for this difference between systems is not understood but may be due to different types of peat used, different wastewater strengths, or different system designs and wastewater loading rates. The new recirculating Puraflo design, in which effluent from the peat filter is recirculated back to the pump chamber for further denitrification, reports a 52% nitrogen loss in preliminary data. It is probably safe to say that most 1-pass peat filter systems are capable of at least a 30% nitrogen removal.

PEAT SYSTEM DESIGN AND CONSTRUCTION

A summary of water quality results from a number of residential peat systems is shown in Table 1. These systems include gravity fed peat beds designed by Brooks, and Puraflo modular 1-pass and recirculating systems.

TABLE 1

Notes:

Brooks refers to simple Brooks design peat bed
Puraflo refers to Puraflo 1-pass filter, except 1 system designed to recirculate.
*** average value for 10 residential systems sampled for 1 year
* one value only, **not** an average

System type	**# of samples**	**TDN mg/L septic tank**	**TDN mg/L peat**	**% removal**	**BOD mg/L septic tank**	**BOD mg/L peat**	**% removal**	**Fecal FC/100mL septic tank**	**Fecal FC/100mL peat**	**% removal**	**TSS mg/L septic tank**	**TSS mg/L peat**
Brooks residence Ontario	6	63	22	65%	160	<1	99%					
Brooks residence Ontario	2	39	25	36%	138	27	80%					
Brooks residence Wellfleet	10	126	84	44%	623	45	93%	13,690,000	1,242	>99%	138	10.6
Brooks church Eastham		64	44	32%	117	3.8	97%	127,761	26.8	>99%	42.5	12.5
Puraflo 1-pass resid. AL	***	50	30.5	40%	132	17.6	86%	610,000	57,665	93%		
Puraflo 1-pass resid.MD	11	52.5	36	31%	173	4.5	97%	91,622	2,162	98%		
Puraflo recirc resid.MD	4	54*	24.8	53%	68*	2.2	97%	79,000*	4	>99%		

The simple **gravity-fed peat bed designed by Brooks** is constructed in the same manner as a Title 5 system and requires about as much time and labor with the exception of the additional time required to load and compact the peat. The septic tank and distribution box are installed in the typical manner and the leaching bed is excavated. Next, the leaching bed is filled with lifts, or layers of peat. Each layer of peat is compacted, using adults walking over the area repeatedly in snowshoes, before the next layer is added. When the bed is filled with about 2.5 feet of compacted peat, trenches are cut in the peat. The trenches are lined with gravel. Distribution pipes are laid in the trenches on top of the gravel with peat surrounding the sides of the pipes (the gravel is not necessary for the treatment process but serves to reduce clogging of holes or scouring of the peat surrounding the distribution pipe). A minimum of 24 inches of peat should underlie the distribution piping. An additional 8-14 inches of compacted peat is laid over the piping with the result that the top of the peat bed is slightly mounded (to promote rain runoff) at the ground surface. No additional fill is needed as the peat must remain open to the air to assure proper treatment. The system can be planted with grass or shallow rooted plants. The system is sized so that the peat receives a <u>wastewater loading of 1 gal/s.f./day.</u>

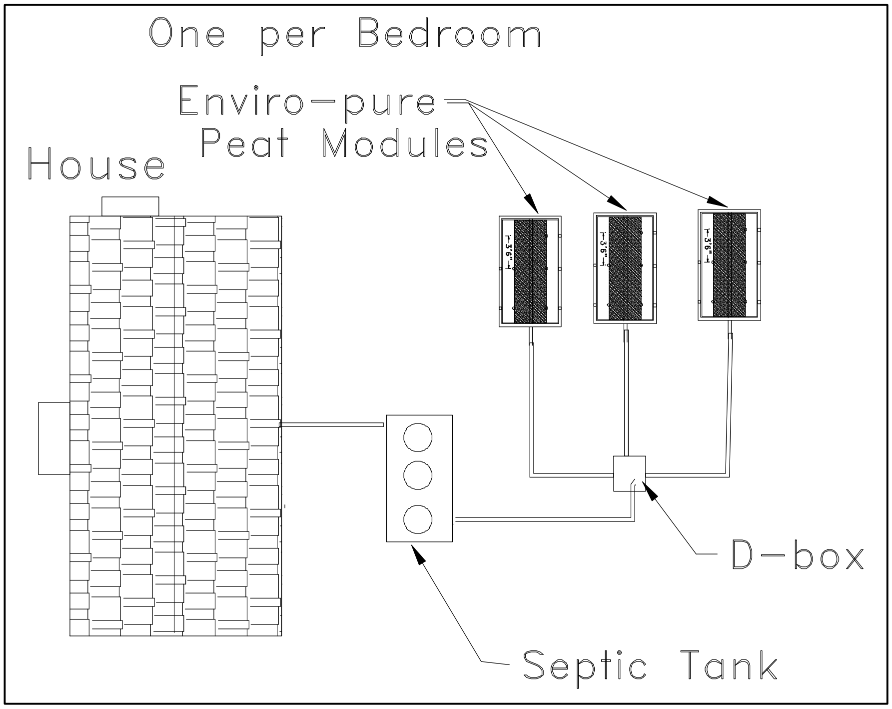


Figure 7. Simplified schema of a Enviro-pure modular peat system.

Information on the system can be obtained from Brooks Technologies, Inc., RR 1 Box 753, East Eddington, ME 04428 (207) 843-6389. A typical system installed on Cape Cod costs about $2000-3000 above a conventional Title 5 system: the peat costs approximately $1000; trucking fees to bring the peat from Maine are about $800; and Dr. Brooks' fee to oversee design and construction is $1000. The system requires no maintenance other than periodic pumping of the septic tank and weeding of the peat bed surface if it is not mowed.

The modular **Enviro-pure**^{TM} system (Figures 4 and 7), also developed by Dr. Brooks, is easier to install because the peat filter modules arrive pre-assembled. Each Enviro-pure module consists of a precast concrete tank 10.5 feet long by 6.3 feet wide by 3 feet high. To construct the system the septic tank and distribution box are first installed (septic tank effluent may be pumped up to the distribution box if necessary). The base in which the modules will sit is excavated and filled with a 6 inch base of clean coarse sand or crushed rock. The standard Enviro-pure module has drainage holes in the bottom and lower sides. It is designed so that the effluent, after flowing through the peat filter, leaves the module and enters the base material surrounding the module where it can infiltrate into the underlying soil. The base on which the modules sit is sized for the long-term acceptance rate of the underlying soil. The modules are installed at a depth that places the bottom of the modules in the native soil that will be used to dispose of the effluent (i.e. below the topsoil). The modules are put in place and backfilled with loamy sand fill at a 4:1 slope from the outer limits of the modules to the original grade. The top of the peat in the modules is left open to the ground surface for air exchange but may be seeded with grasses. Alternatively, the Enviro-pure module can be designed with no drainage holes so that the effluent flows to an underdrain pipe for discharge to a conventional leaching facility located separately.

Each module will provide treatment for 90 gallons of wastewater; a typical 3 bedroom design requires 4 modules. The modules are loaded with wastewater at a rate of about 1.5 gal/sf/day. Modules cost $1250 each plus trucking from Maine. Information on the Enviro-pure system is available from American Concrete Industries, RFD 5 Box 100, Bangor, ME 04401.

The Puraflo^{TM} Peat Biofilter (Figures 5,6, and 8) is constructed of modular units of polyethylene filled with biofibrous peat treatment media. In this system wastewater flows from the septic tank to a pump chamber. A small submersible pump sends a dose of effluent under pressure to a central manifold that flows to a grid of distribution pipe in each module. The effluent is dosed onto the peat media where it moves through a depth of 30 inches of peat media over a period of 36 to 48 hours. After the effluent has filtered through the media it exits the modules through holes in the bottom. The modules sit on a 6 inch deep base of crushed stone. The base serves as the percolation area for final disposal of the effluent. In sandy soils a 500 gpd system usually covers a 320 s.f. area. The modules are typically placed at ground level to utilize the upper layers of the soil for effluent treatment and dispersal. In poorly draining soils radiating drains are connected to the footprint percolation area to increase the area for disposal. Effluent can also be underdrained from the modules and piped to another location for disposal.

A standard 4 module single home system will treat up to 500 gpd. Additional modules can be added for each additional 125 gpd of design flow. Surface dimensions of each module are 7 by 4.5 feet. Wastewater is loaded to the module at a maximum of 3.9 gal/s.f./day, a loading rate significantly higher than that used in the Brooks design. Maintenance of the system is minimal and primarily involves inspecting the pump and electrical controls as well as annual inspection of the peat surface.

In an effort to maximize nitrogen loss, Bord na Mona has recently introduced a design change whereby a portion of the effluent that has passed through the peat filter is recirculated back to the pump chamber. It is assumed that effluent leaving the peat filter has been fully nitrified. The pump chamber is presumably anaerobic and high in carbon due to inflow of sewage from the septic tank. These conditions are intended to promote denitrification, thereby enhancing nitrogen loss. In this type of design the peat filter functions in much the same way as a recirculating sand filter, substituting peat rather than sand as the filtration media where nitrification occurs.

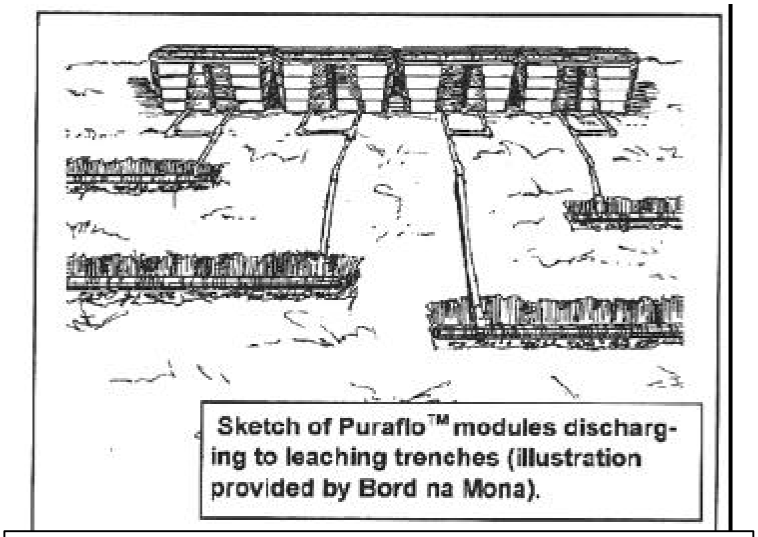


Figure 8. Sketch of Puraflo™ modules discharging to leaching trenches (illustration provided by Bord na Mona).

The Puraflo system has been used as an a approved alternative system in Ireland and the United Kingdom since 1988 and more than 1000 systems are now in operation. A number of Puraflo units have been installed in coastal areas of Alabama and Maryland as demonstration projects and are currently being monitored. A standard 4 module system which will treat up to 500 gpd costs $6700-7000 delivered. This cost includes the peat modules, piping, pump chamber and pump, and a representative from Bord na Mona to oversee installation. It does not include the septic tank or cost of the contractor for installation of the system. The system is distributed in the U.S. by Bord na Mona Environmental Products, Inc., PO Box 77457, Greensboro, NC 27417, (910) 547-9338.

It is important to recognize that there are significant differences between the Puraflo system and the two peat systems designed by Brooks. First, different types of peat media are used. Peat used in the Brooks systems is derived from sphagnum moss and is more finely textured than the Puraflo peat media which is derived from moderately decomposed roots of the plant Eriophorum (bog cotton) and is coarser, more fibrous, and fluffier. This means that the Brooks peat media is more densely compacted in the peat filter than the Puraflo peat media. Wastewater loading rate (gal/s.f./day) is also significantly lower in the Brooks systems (1-1.5 gal/s.f./day) vs. the Puraflo system (3.9 gal/s.f./day). The finer, more compact peat media and lower wastewater loading rate in the Brooks systems probably account for the greater removal of fecal coliform seen in these systems compared to the Puraflo system. The Puraflo system, on the other hand, probably functions more like an artificial media trickle filter; the peat media is coarse and drains relatively rapidly thus acting much like the synthetic media used in other trickle filters.

WHAT ARE THE ADVANTAGES OF A PEAT SYSTEM?

Peat systems have certain advantages. Simple peat systems can flow by gravity and be designed to be completely passive. Maintenance of peat systems is minimal. The cost to install peat systems is relatively low and the only costs associated with operating the systems are routine. Modular systems, when gravity fed, have similar advantages. If the modules are used in conjunction with pump chambers, and in the case of Puraflo's more recent design change to achieve recirculation, these systems appear competitive with recirculating sand filters. Peat systems are capable of producing effluent of excellent quality in terms of BOD, TSS, and fecal coliform reductions. Some amount of nitrogen loss also occurs. Peat systems retain their ability to treat sewage even when used intermittently. Peat systems also appear to function well in cold temperatures as has been demonstrated by successful installations in Maine, Canada and Alaska. The true efficacy of these systems in Barnstable County may emerge as more data are gathered on their nitrogen removal capability.

A WORD OF CAUTION

Regulatory officials in Maine have issued a caution to designers and installers regarding peat systems. Apparently a few of the systems have clogged. We do not have all the details but it appears that the failures are related to improper installation and deviation from the original design specifications. So far, in Barnstable County, we have not encountered that problem despite one system having excessively high septic tank BOD, fecal coliform and nitrogen being fed to it.

REGULATORY STATUS

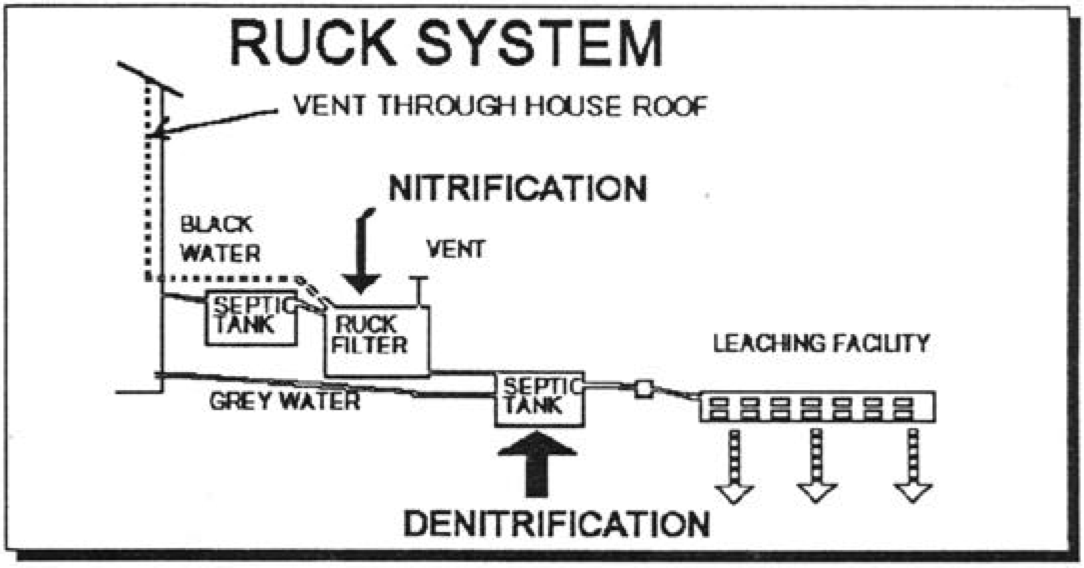
Peat systems designed by Brooks are an approved system in the state of Maine. Approximately 500 Brooks peat bed systems have been installed in Maine, Canada, and elsewhere in the U.S. Approximately 50 Enviro-pure systems have been installed in various locations, including the shellfish hatchery on Martha's Vineyard. Aside from its European installations, Bord na Mona has received limited approval for installations of Puraflo systems in New Jersey, Maryland, Virginia, Ohio, North Carolina, Kentucky, and Alabama.

Peat systems are still considered experimental systems in Massachusetts and none have received any type of approval (piloting/ provisional/general) by DEP for use in this state.

The RUCKÒ System

(From Issue 4)

In the RUCK system the household's greywater (washwater) and blackwater (toilet and kitchen sink wastes) are plumbed separately and flow to separate septic tanks (Figure 1). The blackwater flows from the septic tank to the aerobic RUCK filter where it is nitrified and then flows to the anaerobic greywater septic tank for denitrification. The entire system consists of two septic tanks, the RUCK filter, and a conventional leaching facility, all of which are located below the ground surface. In some situations the system may be passive, requiring no pumps or other moving mechanical parts (unless finished effluent must be pumped up to an elevated leaching field to achieve adequate separation to groundwater).



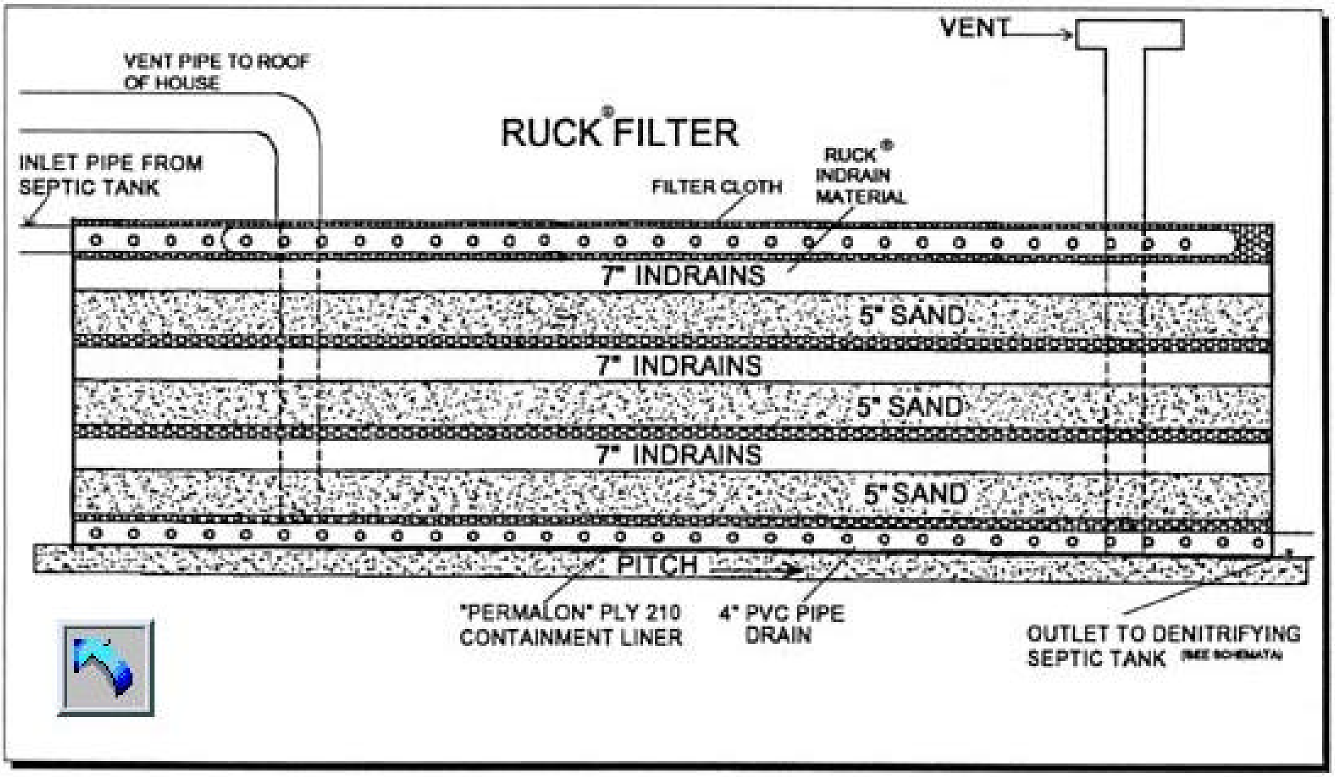
The treatment process is as follows: blackwater flows to a conventional septic tank where solids settle. The blackwater effluent then flows to the RUCK aerobic filter where it is nitrified. The RUCK filter is composed several layers of in-drains which are overlain by layers of sand and filter cloth. The in-drains are composed of the proprietary material of the RUCK system and provide air to the filter so that it remains aerobic. A schematic diagram of the RUCK filter is shown in Figure 2. The in-drain media and the sand support the growth of nitrifying bacteria. As the effluent trickles through the filter, nitrification occurs. The effluent is collected by a drain at the bottom of the RUCK filter from which it flows into the greywater septic tank. The greywater septic tank is anaerobic and the greywater provides a rich source of carbon which supports the growth of denitrifying bacteria. Denitrification of the effluent is accomplished by passive mixing of the RUCK filter-treated blackwater with the greywater in this septic tank. After treatment in this tank, finished effluent flows to the leaching facility for disposal.

DEP, in its General Approval for the RUCK system, recognizes that the system is capable of producing finished effluent with total nitrogen content of 19 mg N/L. Limited data show that the system may also be capable of approximately 50% removal of phosphorus.

As stated above, there are no moving mechanical parts so the system requires little maintenance other than periodic pumping of the blackwater septic tank. The RUCK filter is designed and sized for minimal maintenance. The RUCK system is designed to operate passively and flow by gravity. However, because of the number of separate components and the necessary drop in elevation between each component the leaching facility will be located at a relatively deep elevation. A 10 foot depth from the land surface to groundwater is required in order for the leaching facility to located deep enough to accommodate gravity flow. If a 10 foot depth to groundwater does not exist, the leaching facility will have to be raised relative to the rest of the system and the finished effluent pumped up to the leaching facility. This requires the installation of a pump chamber and pump.

DEP requires that all RUCK systems be under a maintenance agreement and that a Massachusetts Certified Wastewater Operator will be responsible to oversee operation of the system. Holmes and McGrath, Inc., the designers of the RUCK system, will provide a contract for operation and maintenance. Preliminary maintenance agreements are $800.00 per year which includes $600.00 in water testing fees. DEP requires that influent and effluent from the system be monitored quarterly for pH, BOD, TSS, TKN, nitrate and ammonia.

The cost of installation of a typical RUCK system for a three and four bedroom home is approximately $7250.00 and $9250.00, respectively, above the cost of a Title 5 system. Holmes and McGrath, Inc., 200 Main Street, Falmouth, MA 02540 (800) 874-7373, are the Massachusetts licensed designers and installers of RUCK systems. Local engineers can also be licensed to design RUCK systems and local contractors can be trained to install these systems.



Trickling Filters

(From Issues 4 and 5)

TRICKLING FILTERS - GENERAL

The trickling filter is a technology that can generally be described as the "trickling" of liquid over a media to achieve treatment. The media can be a wide variety of materials ranging from pieces of cylindrical plastic to stones or foam blocks. The technology can be used to provide a final "polish" to the effluent, or it can be the intermediate step in an overall process. As applied to onsite septic systems, trickling filters receive septic tank effluent. As the effluent passes or trickles over the media, available oxygen (as these systems are usually well ventilated to supply fresh air), is used by nitrifying bacteria to convert the ammonia in the effluent to nitrate and the BOD is reduced. After passing over the filter media, the effluent is sometimes discharged to the soil absorption system or leaching facility. If denitrification is desired, a portion of the filtrate is recycled back to an anaerobic chamber such as the septic tank. It should also be noted that, in many cases, the growth on the filter media thickens to the point where there are some anaerobic microzones in the media in which denitrification can take place.

If you haven't seen the parallel already, review the chapter on recirculating sand filters. Can you see that the RSF is really a trickling filter? The difference is that media in trickling filters generally is much more open (contains relatively large pore spaces compared with the sand filter), and the residence time in the media is comparatively shorter than a sand filter.

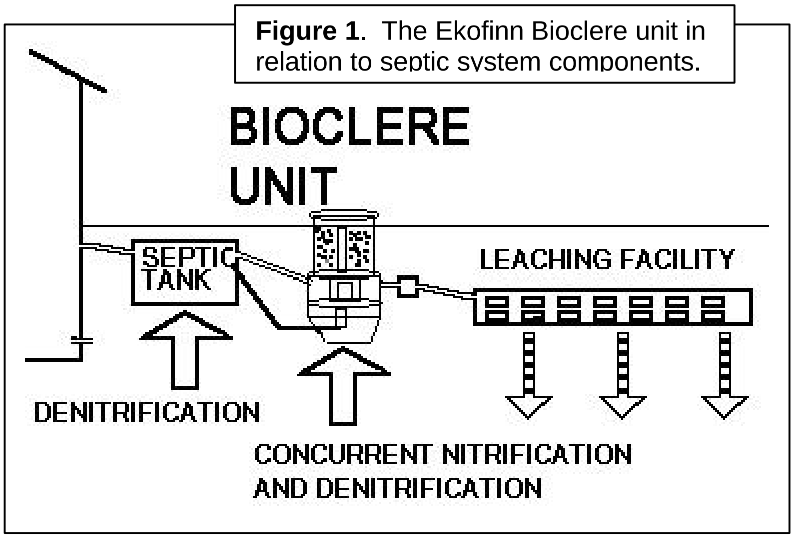
In this chapter, we discuss three trickling filters, the Ekofinn Bioclere (which is the most popular in Massachusetts due to its approval status), the Waterloo Biofilter, and the Orenco Trickle Filter. These latter two are being variously tested in demonstration projects in Barnstable County.

EKOFINN BIOCLERE

The Bioclere is a modified trickling filter that utilizes a stable fixed film process for simultaneous nitrification/denitrification. The unit can also be designed to incorporate recirculation of wastewater to the anaerobic zone in the septic tank for more complete denitrification. The Bioclere unit is purchased as a module that is installed in the ground between the septic tank and the leach field. The placement of the Bioclere unit in relation to other system components is illustrated in Figure 1. The unit itself is illustrated in Figure 2.

The treatment process is as follows: wastewater first flows to a conventional septic tank where primary settling occurs. Effluent from the septic tank then passes to the Bioclere unit and is received in the baffled sump portion of the Bioclere. A dosing pump distributes this effluent up and over a synthetic media bed at varying recirculation rates. Oxygen is introduced to the media chamber through the use of a small fan. Nitrifying

Figure 1. The Ekofinn Bioclere unit in relation to septic system components.



bacteria form a biomass in the aerobic environment of the media bed and this is the site of nitrification. As the biomass thickens, it forms anoxic and anaerobic zones which establishes the conditions for simultaneous denitrification. Approximately 20% of the total nitrogen can be lost through this process. After flowing over the media bed, wastewater returns to the sump portion and is further recirculated over the media. In systems designed for more complete denitrification, a portion of the water in the sump can also be shunted back to the septic tank through the use of a second pump located in the sump portion of the Bioclere. Recirculation of effluent to the septic tank where anaerobic conditions and high nutrient levels prevail allows efficient and more complete denitrification to occur.

DEP, in its Provisional Approval for the Ekofinn Bioclere unit, recognizes that the unit is capable of producing finished effluent with total nitrogen content of 19 mg N/L. The Bioclere unit is also capable of 90-95% removal of BOD and total suspended solids and meets or exceeds secondary treatment standards for these parameters. BOD and total suspended solids in finished effluent are both consistently less than 30 mg/L. National Sanitation Foundation testing data show that the unit also appears capable of 1-log reductions in both total and fecal coliform.

When designed for full denitrification, the unit operates with two pumps, a fan, and a timer. Routine operation and maintenance by a qualified technician is necessary. The septic tank must also be pumped at normal 2-3 year intervals. DEP requires that all Bioclere systems be under a maintenance agreement and that a Massachusetts Certified Wastewater Operator will be responsible to oversee operation of the system. AWT Engineering Inc., the distributors of the Bioclere system, will provide a contract for operation and maintenance. DEP also requires that influent and effluent from the system be monitored monthly for the first six months and quarterly thereafter for the following parameters: pH, BOD, TSS, TKN, nitrate and ammonia.

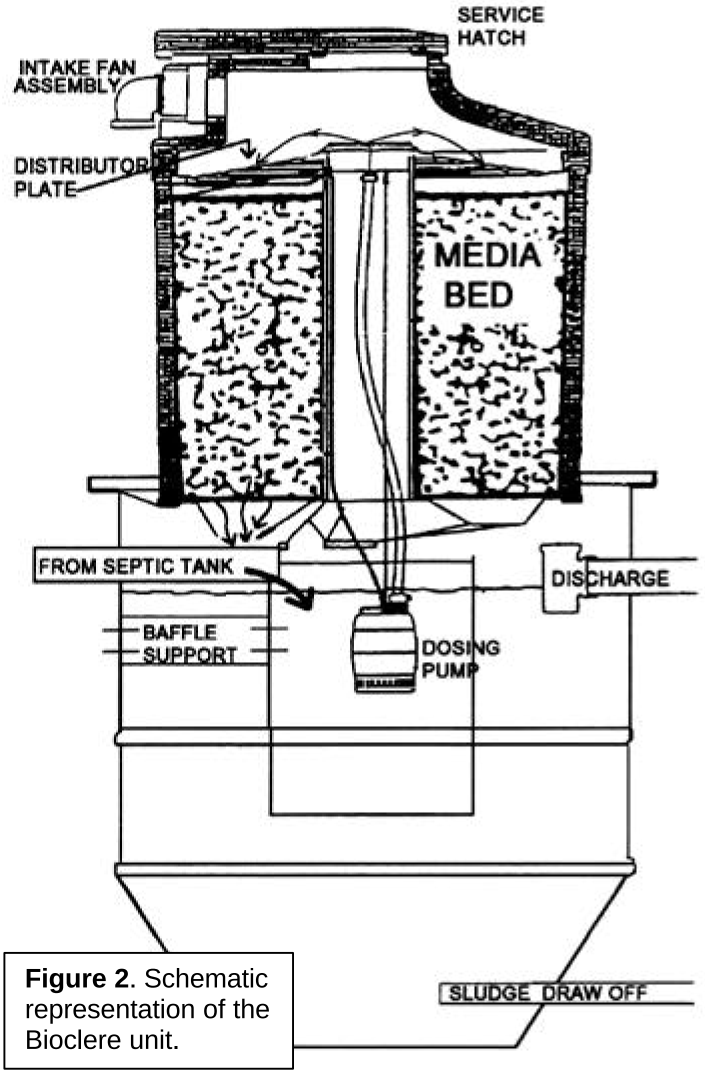


Figure 2. Schematic representation of the Bioclere unit.

The cost of a residential Bioclere unit, which can treat up to 1000 gpd, is approximately $4600.00. The system also requires a septic tank; a precast concrete 1500 gallon tank costs approximately $1000. There are also additional labor costs for installation of the unit and the cost of a conventional Title 5 leaching field. For the installation "credits" as of

June, 1997, see the chapter on DEP Approval Process for Alternative Onsite Septic Systems. The system is becoming increasingly popular in Barnstable County.

The state of Massachusetts recognizes use of Bioclere systems for flows from a single residence to 10,000 gpd with varying strengths of wastewater. Installations include schools, nursing homes, supermarkets, health clubs and restaurants. A number of Bioclere units have been installed on Cape Cod in the towns of Yarmouth, Falmouth, Dennis, Harwich, and Chatham. (Issue 3 of this newsletter provides a review of many of these systems). Health Agents in these towns may be contacted for information on how these systems are performing.

AWT Environmental Inc., BOX 50120, 214 Duchaine Blvd., New Bedford, MA. 02745, (508) 998-7577, are the distributors of the Bioclere in Massachusetts. Mark Lubbers is the contact person.

WATERLOO WATERLOO

For many of you history buffs, Waterloo is that Belgian city where Napoleon finally took his hand out of his jacket and was defeated in 1815 (or was it 1816?). But to alternative septic system aficionados, "Waterloo" references the University of Waterloo in Ontario where researchers have been developing some interesting designs for treating septic wastes. One such design is the Waterloo Biofilter. The filter is basically a box filled with foam-block media. Yes, foam blocks, approximately 2"x2"! The septic tank effluent is distributed over the top of a 6' square by 4' high bed of these blocks to encourage the highly aerobic breakdown of the wastes. Increased ventilation of the system is achieved by using a small fan to draw air through the unit. The high surface area of the foam bed has achieved impressive results in Gloucester and other areas. The schematic for this system is shown in Figure 3. Pretty simple eh?

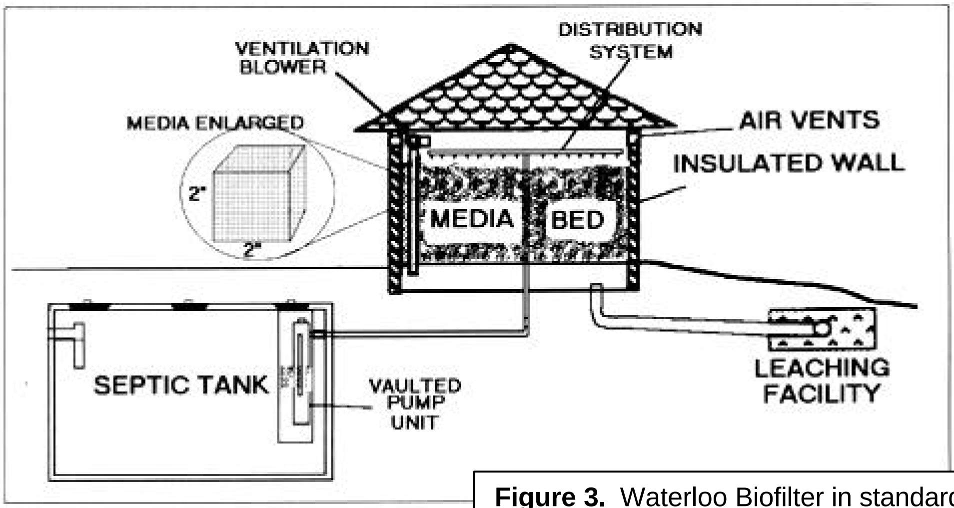


Figure 3. Waterloo Biofilter in standard application.

To give you an idea of the performance, the table on the next page was compiled from data sent to us from Anish Jantrania, the Engineering Consultant up in Gloucester and are for their unit from January - March, 1995. What about nitrogen and the Waterloo? As you can see, the nitrogen removal in the biofilter as it was configured is not terribly impressive. However Gloucester changed the piping this spring to divert some of the flow from the biofilter back to the septic tank, where anaerobic conditions might enhance the denitrification process. Figure 4 shows the configuration of two Waterloo units (one in the Waquoit Bay Demonstration Project, and another in the Wellfleet Harbor Demonstration Project) configured specifically for nitrogen reduction. Results from this modification will be presented in upcoming newsletters. Another exciting prospect for this filter is the development of a phosphorus removal module. Our department may be installing and testing this unit in the coming year under a DEP grant. **Costs?** We are not yet sure what the costs of this unit will be. Much will depend on the housing unit, and whether it is placed above grade on a foundation or whether it is sunk below grade. But keep an eye on future issues of this newsletter for the latest developments.

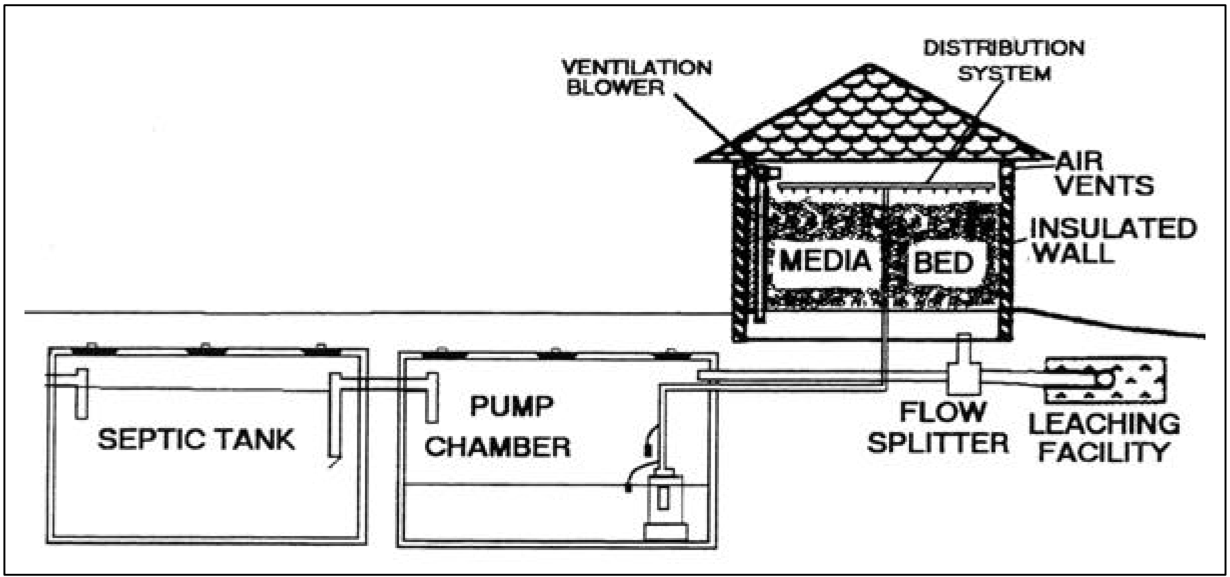


Figure 4. Waterloo Biofilter configured for denitrification.

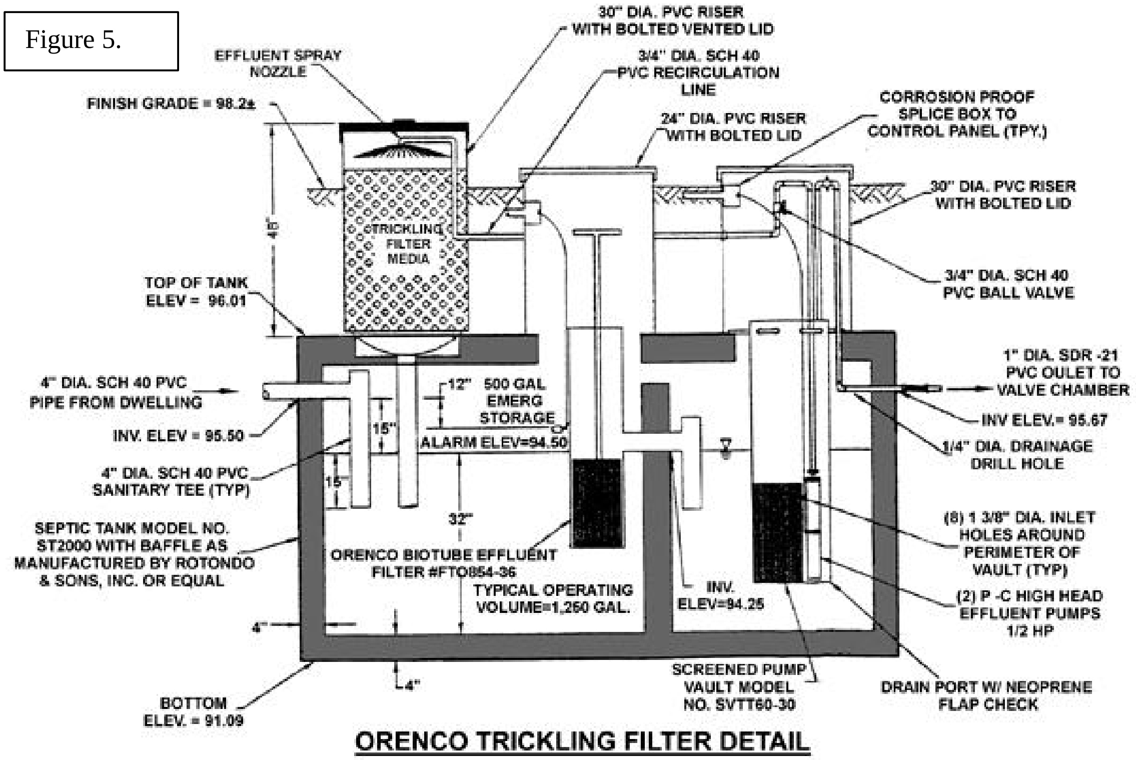
National Onsite Demonstration Project Results - WATERLOO BIOLFILTER
January - March, 1995

Parameter	**Influent**	**Effluent**	**Percent Reduction**
5-Day Biological Oxygen Demand (BOD)	194	16	92%
Total Suspended Solids (TSS in mg/l)	42	11	74%
Dissolved Oxygen in mg/l	1.6	8.1	
Fecal Coliform (#/100 ml)	117,713	924	99%
Total Nitrogen (mg/l)	76.6	60	**22%**
Total Phosphorus (mg/l)	7.2	6.7	7%

ORENCO TRICKLING FILTER

Orenco Systems, Inc., a name well known in the western United States is making inroads in Massachusetts. Their Low-rate Intermittent Sand Filter has certification for general use in Massachusetts, and one installation has been made in Gloucester. Among the variety of other products produced by Orenco is the "trickling filter". This filter uses urethane foam, like the Waterloo Biofilter, in a 30-inch diameter, 48-inch high cylindrical structure that sits atop the septic tank. We now understand, however, that they may be experimenting with various media. The principle is fairly simple. A pump within the septic tank pumps effluent to the top of the filter media, where presumably the first step in the nitrogen-removing process (nitrification or the conversion of ammonium to nitrate) takes place. The filter bed drains back into the septic tank, where the second step in the nitrogen-removing process (the conversion of nitrate to nitrogen gas) takes place. The actual pumping to the filter is based on a timer (Figure 5).

Figure 5.



Again, Gloucester has been first to pioneer the use of the trickling filter, however one has been installed in Wellfleet and is undergoing testing. The Buzzards Bay Project also planning an installation of this type of system coupled with a constructed wetland for final effluent polishing. That system is scheduled to be installed in June 1997. Two additional units may be installed in Wellfleet in the summer of 1997.

To date, the results of the Gloucester installation have been pretty impressive. The table on the next page is a summary of results from Gloucester from January - March 1995.

Parameter	**Influent**	**Effluent**	**Percent Reduction**
5-Day Biological Oxygen Demand (BOD)	142	26	82%
Total Suspended Solids (TSS in mg/l)	53	34	36%
Dissolved Oxygen in mg/l	2.6	2.6	
Fecal Coliform (#/100 ml)	41,130	906	98%
Total Nitrogen (mg/l)	42.3	15.5	63%
Total Phosphorus (mg/l)	5.5	1.4	75

National Onsite Demonstration Project Results - ORENCO TRICKLING FILTER
January - March, 1995

Costs?

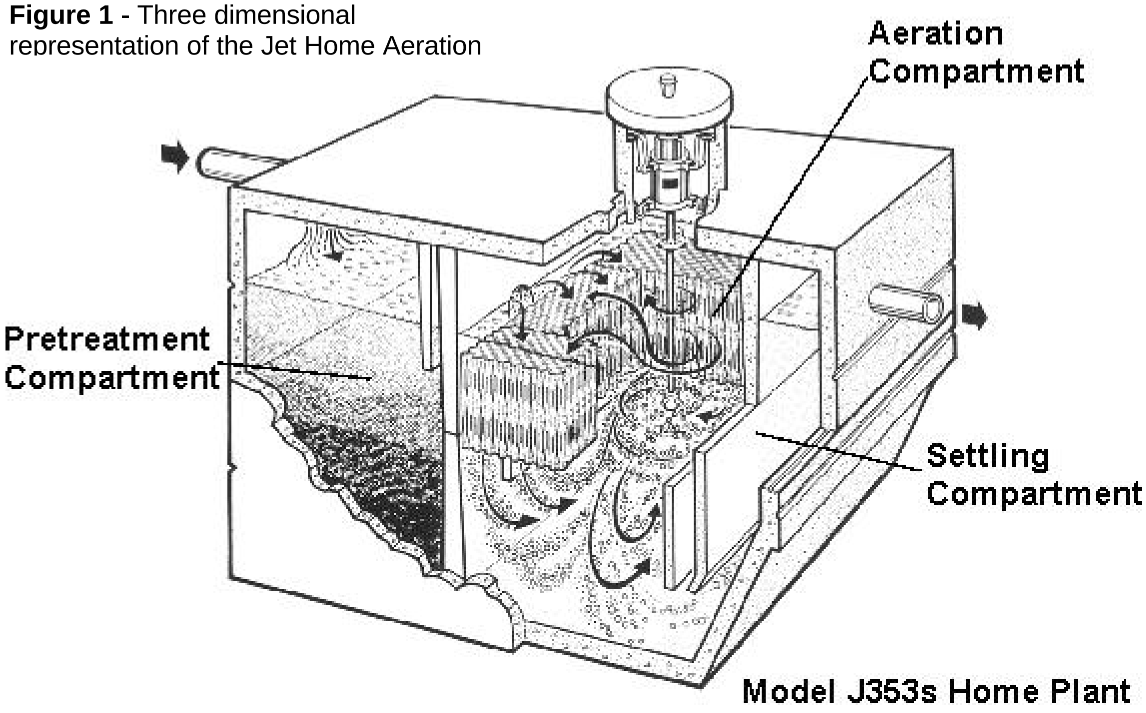
It's difficult to know how the costs will shake out, the trickle filter itself will come in at around $2,500. This includes the filter unit, two pumps and the control panel. We can not really comment on the installation costs yet, but Anish Jantrania in Gloucester says that it's fairly simple. As you might guess, if you want the covers for the system to be at grade, a variance to the maximum -three-feet-below-grade requirement of 310 CMR 15.221:(7) will be needed.

Aerobic Units

JET Aerobic System and Sand Filter

The Jet Home Aeration Plant J-353 is an aerobic wastewater treatment system designed to reduce BOD and TSS in treated wastewater. Wastewater treatment occurs in a three compartment tank (*Figure 1, side view of tank, Figure 2, schematic of system)*.

Figure 1 - Three dimensional representation of the Jet Home Aeration



Wastewater first enters the 476 gallon pretreatment compartment where large organic and inorganic solids settle to the bottom. A sludge layer builds up on the bottom of this compartment, and anaerobic bacteria break down some of the organic matter. Fluid leaves the pretreatment compartment by hydraulic displacement into the aeration chamber through a transfer port. Each end of the port is submerged below the fluid level to prevent passage of grease and floating matter.

In the 607 gallon aeration compartment, fluid from the pretreatment chamber is mixed with aerobic sludge. The aeration chamber contains a mechanical aerator mounted above the chamber in a concrete riser. The aerator consists of an electric motor coupled to a hollow shaft with an aspirator at the end. The aspirator is submerged in the mixed liquor. Rotation of the aspirator induces mixing and the pressure differential draws air from the intake on the top of the riser down the hollow shaft and through the aspirator. As air is injected into the mixed liquor, tiny air bubbles are dispersed from the aspirator. The aeration compartment contains 19 cubic feet of special plastic media that supports the growth of aerobic bacteria. Mixed liquor circulated by the aerator passes through the plastic media as it circulates in the tank and receives treatment by the bacteria on the media.

This allows aerobic degradation of the organic matter to occur.

After treatment in the aeration compartment, the treated effluent is transferred by simple hydraulic displacement to the 114 gallon settling compartment. There are two baffles between the aeration compartment and the settling compartment. The first baffle is open at the bottom and the second baffle, which is submerged in the aeration compartment, is parallel to the first baffle. Mixed liquor flows between the two baffles and maintains a circulation current in the aeration compartment. Treated effluent flows to the settling compartment through the bottom opening of the first baffle. Suspended solids and biofilm pieces in the treated effluent settle to the bottom of the settling compartment. They are returned to the aeration compartment by means of the circulation current created by the mixed liquor circulating between the two baffles.

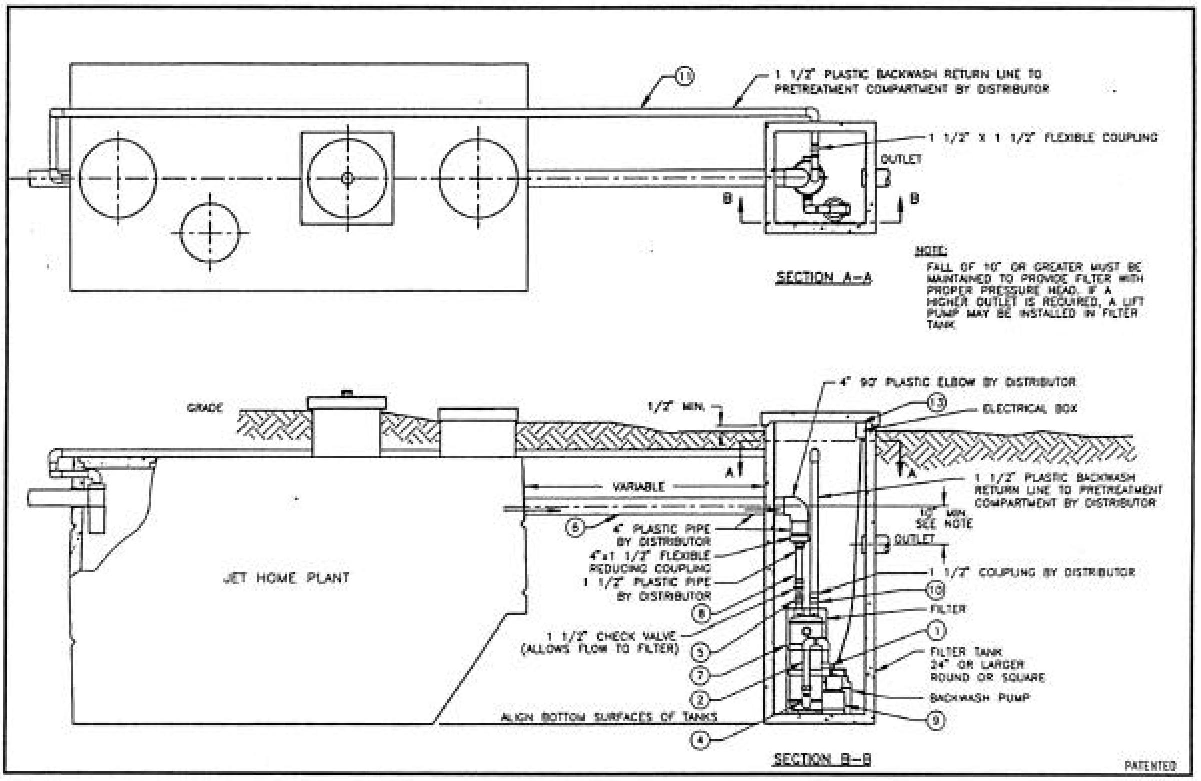


Figure 2 - Schematic representation of the Jet Home Aeration Plant with sand filter (illustration provided by manufacturer

After settling, effluent leaves the treatment compartment by hydraulic displacement. The effluent flows by gravity to the leach field or may flow to the optional JET Sand Filter for further treatment. The sand filter unit is housed in a separate tank installed near the JET aerobic unit. The Jet Sand Filter J-335 is designed to provide further treatment of aerobic treatment plant effluent. The sand filter is a small modular unit that can easily be installed in a pump chamber or dosing chamber. Effluent from the aerobic unit passes through the sand filter unit that contains a ten-inch depth of sand. In addition to providing mechanical filtration, the sand supports the growth of aerobic bacterial film that further digests sewage. The filter automatically backwashes four times daily. Backwash is transferred to the pretreatment compartment pf the aerobic unit by a backwash pump. The unit may also be configured so that the finished effluent is pumped to a dosing chamber where necessary. Final sand filter effluent BOD and TSS levels of less than 10 mg/l have been observed.

The manufacturer claims that finished effluent from the JET Aerobic unit will average 20-25 mg/L of both BOD and TSS. Preliminary results also suggest that the unit may be capable of nitrogen reduction if operation of the aerator is controlled by timer. A pilot installation in Rockland, MA has been operated so that the air supply is on during the day and is shut off at times during the night. This presumably allows the media in the tank to become anoxic during the night so that denitrification can occur. When operated in this way, an approximately 50% reduction in nitrogen was seen in limited testing. DEP has not recognized any nitrogen credit for the unit to date, however.

The JET Aerobic unit has received Remedial Use approval from DEP for use where the system design flow is 450 gpd or less. Based on the unit's ability to reduce BOD and TSS, DEP allows a 50% reduction in leach field size or a 2 ft reduction in required depth to groundwater and certain reductions in soil requirements. DEP requires, as part of the system's Remedial Use approval, that the system be inspected and monitored quarterly for at least three years for pH, BOD, and TSS. As part of the sales agreement, the distributor will provide two free inspection visits per year during the first two years of operation of the system. Beyond this, a maintenance contract is available for about $75 per quarter plus sampling costs. The treatment unit should be pumped out when recommended by the operator during service calls. The frequency of this procedure will be dictated by the strength of the waste stream at each unit. Pumping and other service functions are accomplished from the ground level through concrete access covers located on top of each of the three compartments of the tank.

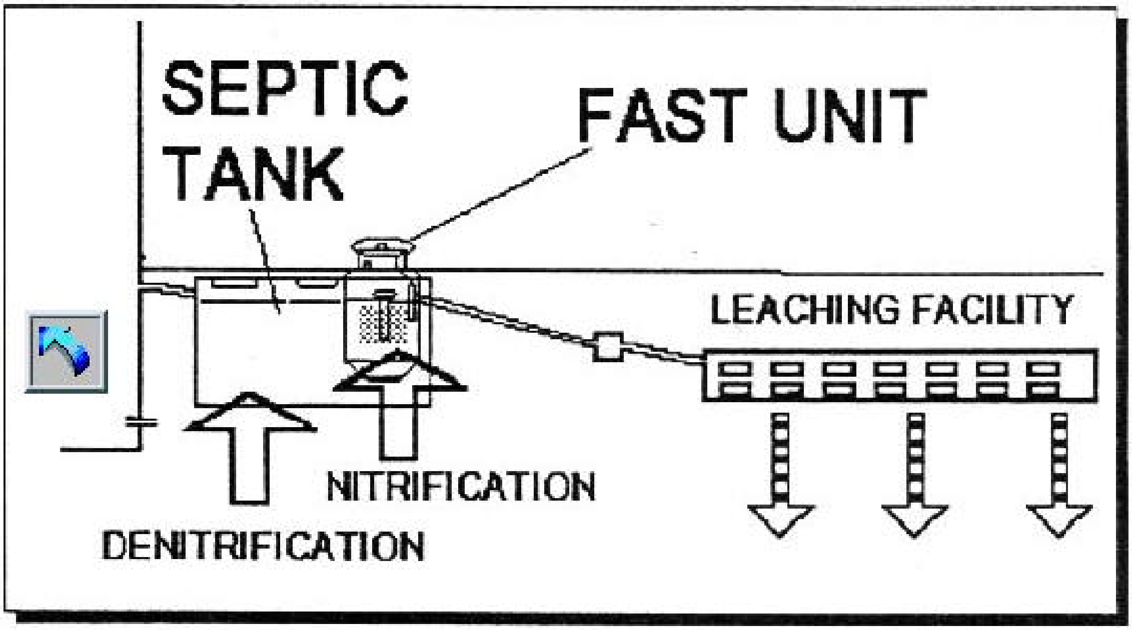
Installation of the JET unit is simple and a septic tank is not required. The unit, containing the aerator, motor, and controls, comes pre-assembled in the treatment tank. Installation of the tank is similar to installing a septic tank. If the optional JET sand filter is used, the chamber containing the sand filter must also be installed, wired, and the installing contractor must install piping for the filter backflush. The JET Aerobic unit costs $5600 delivered to the site plus installation and the cost of the soil absorption system. Treatment capacity of the unit is 450 gallons per day. The JET sand filter, which is optional, costs about $775 plus installation. Local distributor of the JET Aerobic system is Stephen Nelson, Clearwater Recovery, 175 Spring St., Rockland, MA 02370 (617) 878-3849.

Fixed Activated Sludge Treatment -FAST

(From Issue 4)

SMITH AND LOVELESS SINGLE HOME FAST SYSTEM

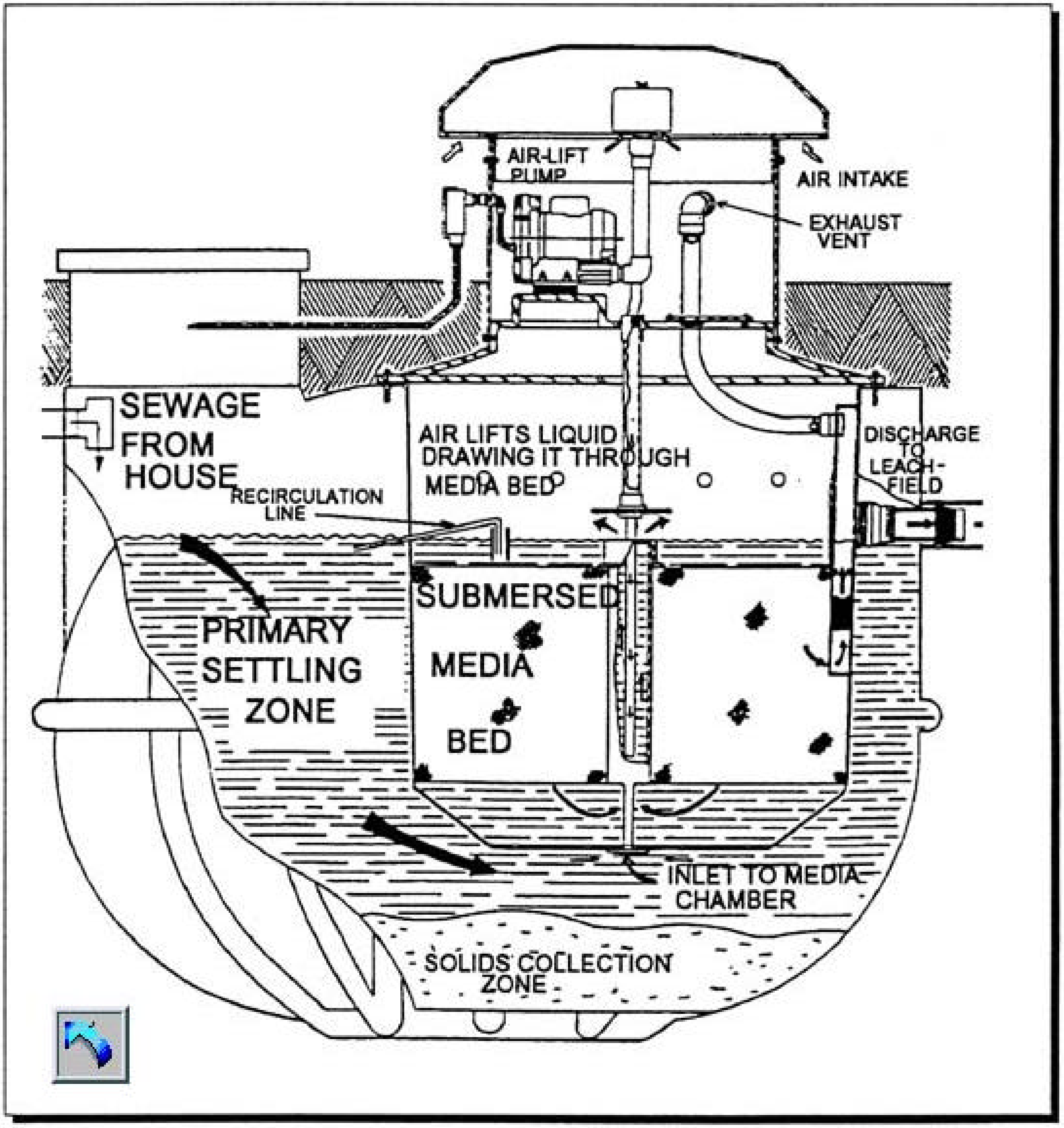
The FAST system uses a Fixed Activated Sludge Treatment process to treat and denitrify wastewater. The FAST process is a two zone design which consists of a primary anaerobic settling zone and an aerobic biological treatment zone. Solids are trapped in the primary settling zone. The aerobic biological zone consists of a submerged media bed which is colonized by nitrifying bacteria naturally present in sewage. Wastewater is recirculated between these two zones allowing both nitrification and denitrification to occur. The FAST unit is purchased as a module which is fitted into a 1500-2000 gallon conventional precast or fiberglass septic tank. Figure 1 presents a schematic diagram of the FAST unit. A detail of the unit itself is presented in Figure 2.



The treatment process in the FAST unit is as follows: wastewater flows from the dwelling into the primary settling zone of the septic tank. Solid matter settles out in the solids collection zone at the bottom of the tank. The FAST unit sits in the septic tank liquid with its media bed submerged. An air blower located above ground forces air down a central tube to the bottom of the submerged media. As the air rises up through the media it acts as an airlift and carries wastewater with it. The wastewater is flows up through and is dispersed over the top of the media bed. The media, which has a high surface area-to-volume ratio, serves as a site for the growth of nitrifying bacteria. The air blower on a residential unit operates at about 200 cubic feet of air per minute, so that the wastewater surrounding the submerged media is turbulent and appears to be actively bubbling. The high rate of air exchange maintains the media in an aerobic state, allowing efficient nitrification to occur. When the wastewater reaches the top of the media a portion flows out through a channel back into the primary settling zone of the septic tank. This zone is anaerobic and is the site of denitrification. With each pass through the media a portion of the wastewater passes out through a baffle and flows to the leaching field. The amount which flows out at any time at is dependent on liquid inflow to the tank, as the liquid level in the tank remains constant. Because the air blower runs continuously the wastewater is recirculated many times through the nitrifying media and the denitrifying anaerobic zone before being discharged. Thus, efficient nitrification and denitrification is achieved.

The two-zone design of the FAST unit provides for a stable wastewater treatment process. Because the media bed is submerged and remains wet, it is capable maintaining bacterial growth during periods of low water use and somewhat extended periods of no use. Also, because the area containing the media has a capacity of about 400 gallons, the wastewater treatment process is relatively stable even when a surge load is delivered to the system.

Figure 2. Schematic of a FAST unit.



The FAST unit is located below the ground surface except for the air blower portion which is elevated about 2 feet above ground level. However, it is possible to locate the air blower unit remotely, up to 60 feet away, from the FAST unit. For example, the air blower could be located in a nearby garage or shed. In this case, only a vent from the FAST unit will show on the ground surface.

DEP, in its Provisional Approval for the FAST unit, recognizes that the unit is capable of producing finished effluent with total nitrogen content of 19 mg N/L. The FAST unit is also capable of 90-95% removal of BOD and total suspended solids (TSS). BOD and TSS in finished effluent are both consistently less than 30 mg/L.

These effluent concentrations exceed secondary treatment standards for BOD and TSS which require that a minimum of 85% of influent BOD and TSS be removed and that BOD and TSS in finished effluent not exceed 30 mg/L. Limited data suggest that the unit is capable of a 1-log reduction of fecal coliform. A UV disinfection unit is also available for systems where the leach field has inadequate separation to groundwater; the UV disinfection unit is purportedly capable of producing effluent with fecal coliform consistently less than 10 FC/ 100 ml.

Operation and maintenance of the unit appear to be fairly simple. The only moving part of the unit is the air blower. This makes mechanical failure unlikely and simple to remedy should it occur. The air blower is also equipped with an alarm system which is activated if the blower fails. If the submerged media starts to clog and wastewater flow through the media slows, the air pressure in the media rises and this also activates the alarm on the air blower. Smith and Loveless recommend that the solids be pumped from the bottom of the tank once a year. Units equipped with a UV disinfection unit will require more frequent maintenance to ensure that the UV unit is functioning effectively. DEP requires that all FAST systems be under a maintenance agreement and that a Massachusetts Certified Wastewater Operator will be responsible to oversee operation of the system. J and R Engineered Products, Inc., the New England distributors of the FAST system, will provide a contract for operation and maintenance and may be contacted regarding the cost of this contract. DEP also requires that influent and effluent from the system be monitored monthly for the first six months and quarterly thereafter for the following parameters: pH, BOD, TSS, TKN, nitrate and ammonia.

The cost of a residential FAST unit, which can treat up to 900 gallons per day, is approximately $5000.00. The unit must be installed in a 1500 or 2000 gallon septic tank; a precast concrete tank of this size costs $1000-1500. The unit can be retrofitted to an existing 1500-2000 gallon septic tank, provided the tank is watertight and the dimensions of the tank are sufficient to allow 16-18 inches of liquid depth below the FAST unit. In addition, there are labor costs for installation of the unit plus the cost of a conventional Title 5 leach field. The optional UV disinfection unit costs about $1000.00. Several residential FAST systems have been installed in the towns of Cohassett, Hingham, and Hull. These units are becoming increasingly popular in Barnstable County. A large commercial FAST was installed at the Coonamesset Inn in Falmouth, and appears to be achieving very substantial nitrogen removal. In addition, the "99" Restaurant in Mashpee uses a FAST unit.

The FAST system is manufactured by Smith and Loveless, Inc., 14040 Santa Fe Trail Drive, Lenexa, KS 66215. Sole New England distributors are J and R Engineered Products Inc., 271 Leonard St., Raynham MA 02767 (508) 823-9566.

Sequencing Batch Reactors

(From Newsletter 8)

This chapter focuses on a new set of technologies that to some extent use the batch-type technology for the treatment of septic wastes. Batch technology, as its name implies, treats sewage in "batches". This type of technology can be contrasted with the majority of alternative technologies covered in this newsletter up to now, that treat septic tank effluent in a continuous stream that passes over or through a media for the nitrification step of the process (conversion of ammonia to nitrate) and then returns to an anaerobic part of the system (sometimes the septic tank) for the denitrification step (the conversion of nitrate to nitrogen gas). Batch technologies covered in this issue of the newsletter are ones that alternately supply and deprive batches of effluent with air so that the nitrification/denitrification steps can occur, even in the same vessel.

Batch technology is most commonly employed in larger treatment systems that have the ability to control the flows through the treatment plant by various valves, pumps and storage tanks. The advantage of batch technology is better process control. By this we mean that operational details such as dissolved oxygen necessary for nitrification, and exact times needed for denitrification, can be better controlled by the use of timers, fluid pumps, valves, and air blowers. Although at the outset these systems may seem complicated, their advanced treatment, well proven on the large scale, holds promise that the right recipe can be found to remove contaminants of choice - in our case nitrogen! The challenge for these technologies will be to provide a cost effective way to treat sewage onsite, amidst some stiff competition. Although it is still too early to tell what "niche" in the overall onsite treatment world batch technology will fill, it seems evident that at flows slightly above the single family use (small collective systems in cottage colonies, trailer parks, small clusters of homes, etc.), these systems may find their cost effectiveness optimum.

Amphidrome® by Tetra®

New to onsite treatment, but certainly not new to municipal waste treatment, Tetra Technologies, Inc., through its affiliate FR Mahoney & Associates, Inc, of Rockland, Massachusetts is developing and introducing the Amphidrome system. This system merges two proprietary technologies, the ColOX® System for the nitrification of the waste, and Denite® for the denitrification of the waste. One system was installed and is undergoing monthly testing as part of the Waquoit Bay National Onsite Demonstration Project. This installation is the only single-family residential system to date.

ColOX® can best be described as a process where microorganisms, growing on the surface and in the voids between a solid media in a reactor vessel (see the Amphidrome Reactor illustrated on the next page), are supplied air by use of a blower. The microorganisms subsequently process waste and remove BOD and suspended solids. In addition, the high efficiency of oxygen transfer results in high rates of ammonium nitrification. Remember, the conversion of ammonium to nitrate (called ***nitrification***) is the first series of steps necessary for the ultimate denitrification or transformation to nitrogen gas (called ***denitrification***). The Denite® process uses the same reactor vessel and media as the ColOX® process to denitrify waste, again using a fixed film.

"Amphidrome" refers to the linking of the ColOX® and Denite® technologies such that a single reactor vessel serves both technologies in a rhythmic pattern analogous to a tidal cycle in a bay. The effluent passes back and forth through the reactor vessel, alternately being supplied with and deprived of air, for enough cycles to process the waste to a predetermined level.

An Amphidrome system has recently been installed at Stuart's Mall in Swansea, and another has been installed a little closer to home at a location in Mashpee. These latter systems purport to produce an effluent total nitrogen of less than 5 mg/l. Well, they say a picture is worth a thousand words, so, turn the page and follow the proposed sequence of flow through the Amphidrome system as it is being operated at the Waquoit Bay system. The first illustration is a detailed and labeled plan view. Despite the more extensive appearance of the system, it can easily fit almost anywhere a standard system can fit since the reactor vessel is only two feet across and the clearwell can be sized less than 500 gallons.

STEP 1. At 3:30 AM each day, the system discharges to the leaching facility using discharge pump until the low water float is activated.

STEP 2. Flow begins to enter the system causing sewage to flow into the Amphidrome Reactor and equalize elevation in the clearwell. Process air is bubbling up through the chamber, opposite the liquid flow direction. This is a nitrification stage.

STEP 3. Recirculation pump activates and pumps clearwell liquid back trough the Amphidrome Reactor, forcing the liquid level up to the return line. Again, process air is still entering the lower part of the unit and bubbling up through the effluent, continuing to create conditions for nitrification.

STEP 4. Liquid from the treatment unit beginning to flow back to the septic tank via the return line, and mixes with fresh sewage coming in. The now-nitrified effluent enters the anoxic conditions of the septic tank and begins to denitrify using the sewage as a carbon-food source. The recirculation pump in the clearwell goes off and allows the septic tank and clearwell to once again equilibrate liquid elevations. Since the process air is not applied during the passage through the Amphidrome Reactor, anoxic conditions result in denitrification (Denite®) (10AM-11:30AM).

STEP 5 - At 11:30 AM, is a repetition of STEP 3 - process air on (reverse ColOX®)

STEP 6. - At 12:00 noon, is a repetition of STEP 4 with process air on (forward ColOX®)

STEP 7 - At 3:00 PM, is a repetition of STEP 3 - process air on (reverse ColOX®)

STEP 8 - At 3:30 PM, is a repetition of STEP 4 - process air off (Denite®)

STEP 9 - At 4:30 PM, is a repetition of STEP 3 - process air on (reverse ColOX®)

STEP 10 - At 5:00 PM, is a repetition of STEP 4 with process air on (forward ColOX®)

STEP 11 - At 7:30 PM, is a repetition of STEP 3 - process air on (reverse ColOX®)

STEP 12 - At 8:00 PM, is a repetition of STEP 4 with process air on (forward ColOX®)

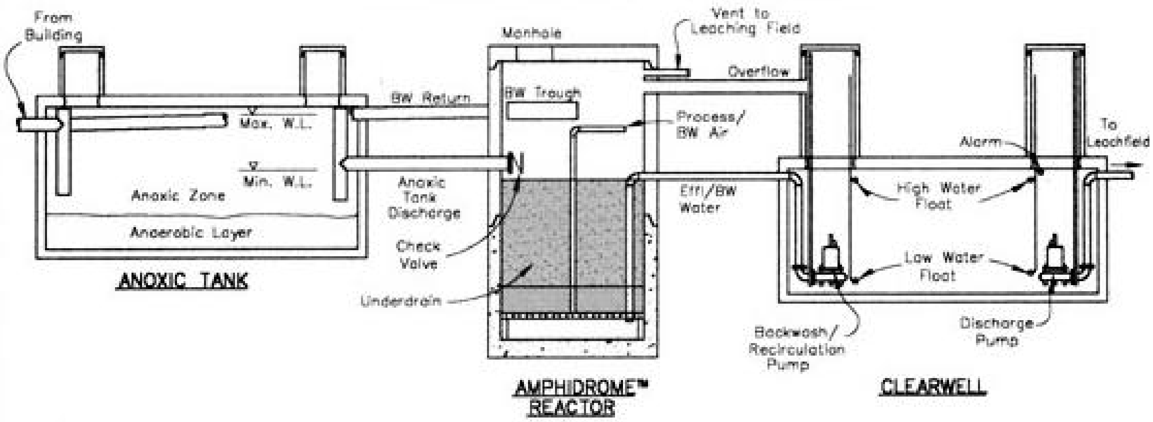
STEP 13 - At 11:00 PM, is a repetition of STEP 3, with higher air input for the purpose of scouring media, dislodging sludge and allowing it to recycle to the septic tank (BACKWASH).

STEP 14 - At 11:30 PM, is a repetition of STEP 4 - process air off(Denite®)

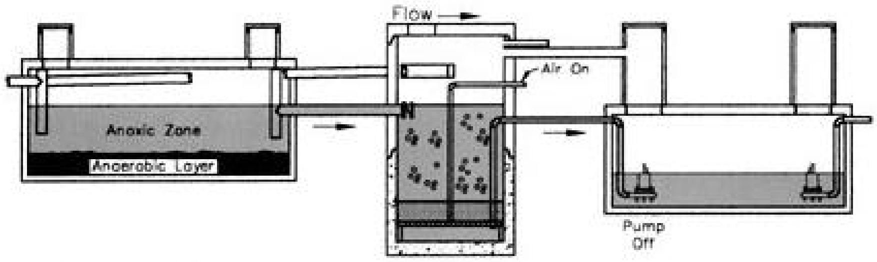
STEP 15 - Is a repetition of STEP 1

Whew!. Before you begin to think about how complicated this all is, you should remember that even a recirculating sand filter activates a pump every half-hour by timer. Performance? Theoretically, the Amphidrome should be able to achieve a discharge concentration of nitrogen at less than 10 PPM, but at this point we can only wait and see. As more of these systems are proposed and installed, DEP will at some point assign a reduction credit. Costs? Still undetermined. We will know more after the Waquoit installation, but as you can see, the costs above and beyond the Title 5 components would be the reactor chamber (actually only concrete piping sections filled with media), air blower, recirculation pump, discharge pump, and control panel including a programmable timer. The operational costs per year would likely be less than $ 100.00 for electricity. We do not yet have information on a maintenance contract or monitoring. If you want further information on the system, Contact Keith Dobie at F.R. Mahoney & Associates, 617-982-9300.

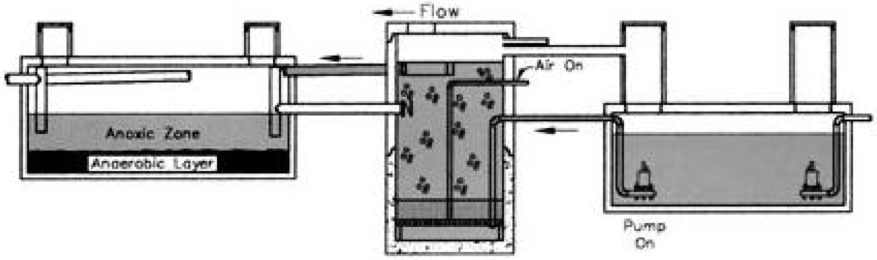
AMPHIDROME™ PROCESS



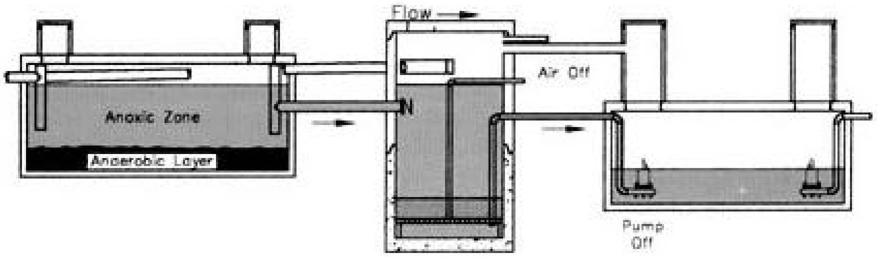
ColOX™ Cycle



Return ColOX™



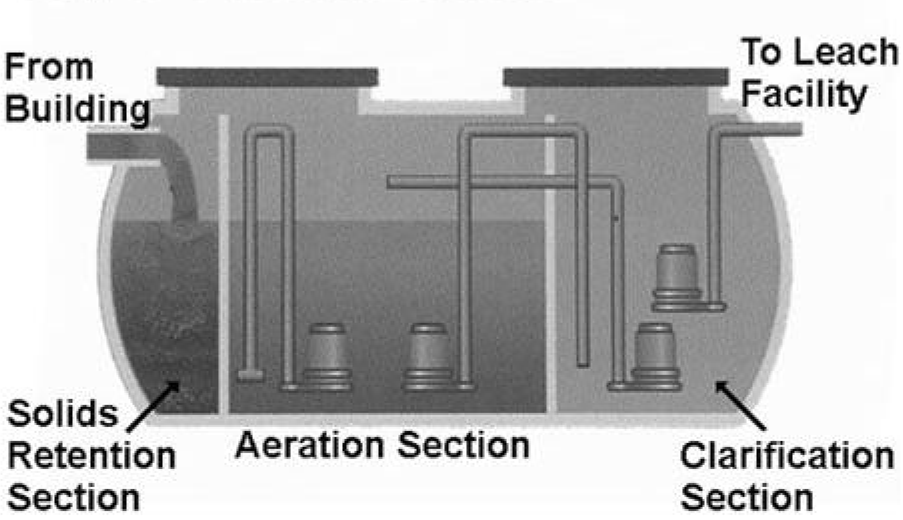
Denite® Cycle



CROMAGLASS® WASTEWATER TREATMENT SYSTEM

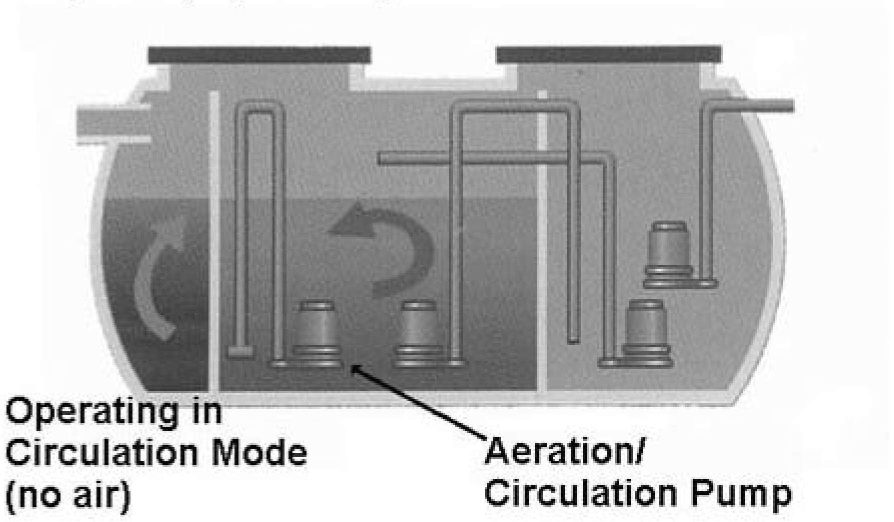
The Cromaglass® wastewater treatment system is another type of sequencing batch reactor. It is designed to operate as a continuously fed activated sludge process with clarifiers that are operated on a batch basis. Treatment operations occur in a single tank module which is divided into three treatment sections. Treatment is accomplished by turbulent aeration of incoming waste in the first compartment and batch treatment of sewage in separate aeration and settling chambers. The treatment process operates as follows:

Step 1 - Fill and Aeration



FILL AND AERATION: Flow enters the solids retention section that is separated from the aeration section by a screen. Inorganic solids are retained behind the half-inch mesh screen. Organic solids are broken by turbulence created when mixed liquor from the aeration section is forced through the screen by submersible aeration pumps. Liquid and small organic solids pass through the screen into the aeration section of the tank.

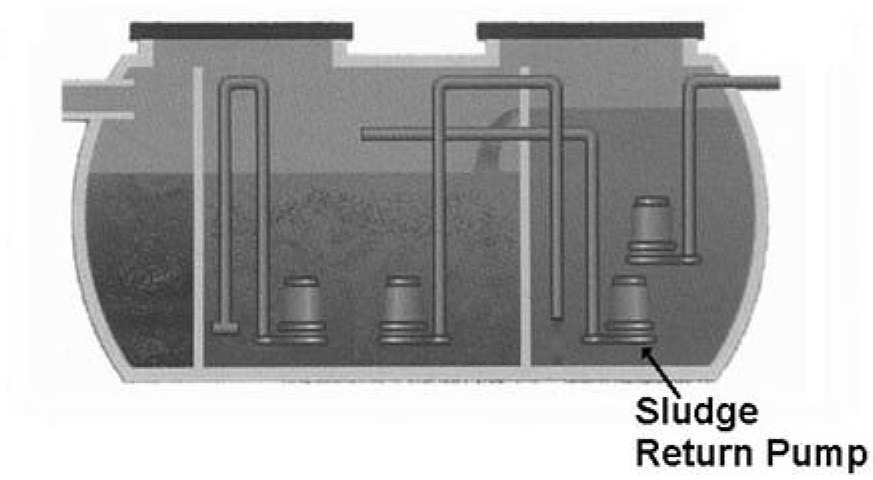
Step 2 - (Optional) Denitrification



AERATION AND OPTIONAL DENITRIFICATION: In the aeration section of the tank submerged pumps with venturi aspirators provide continuous air, mixing and heat. The pumps receive air through pipe intakes from the atmosphere. Aeration proceeds for several hours mixing new inflow with the existing activated sludge that is maintained in the tank. Operating time of the aeration pumps is automatically adjusted to control dissolved oxygen at proper levels suited to the organic loading and treatment requirements of the wastewater

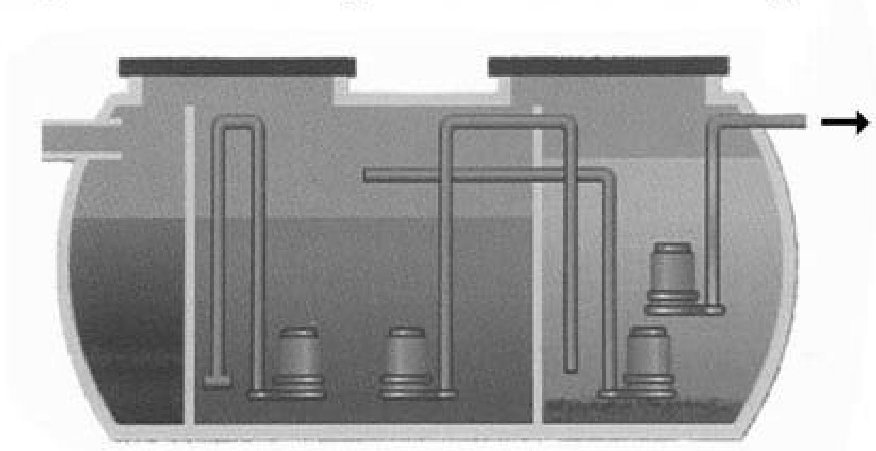
The system can also be configured to achieve denitrification. This is accomplished by providing a time interval during which the air intakes of the venturi aspirators are closed by electric valves. This stops aeration allowing the system to go anoxic so that denitrification can proceed. The pumps continue to mix the sewage in the tank during the anoxic period.

Step 3 - Transfer/Settle



TRANSFER/SETTLE: The treated mixed liquor is transferred by pumps to the clarification section where solids separate and settle under quiescent conditions.

Step 4 - Discharge to Leach Facility



DISCHARGE: After settling, a selected portion of the effluent is pumped out of the clarifier for discharge. Sludge remaining in the clarifier is pumped back in to the aeration area for further aeration and breakdown, or can be wasted to a sludge collection tank.

As with other small sequencing batch reactors, the Cromaglass unit is able to accommodate continuous inflow of new sewage. This new inflow is slowly added to the sewage in the aeration compartment where it begins the treatment cycle. One to six aeration/settling cycles per day are typical for a small residential Cromaglass system depending upon sewage flow.

The Cromaglass system is housed in a single fiberglass tank. The system is sold as a module consisting of tank, internal pumping and sensor equipment and electrical control panel. Five different size modules are available with daily flow capacities from 300-12,000 gpd. Additional modules can be added to a previously installed system if design flows increase. For example, a condominium project with a phased build-out might install 1 or 2 modules initially, and add modules as development proceeds. Because the modules are completely self-contained they can be placed in multiple locations saving additional piping and pumping costs.

The home-sized modules contain two pumps: one for aeration and transfer, and the other for discharge of the effluent to the leaching area. The largest modules (7000-12,000 gpd) contain 9 pumps: two main aeration pumps, two transfer/aeration pumps between the two tanks, two transfer to clarifier pumps, two discharge pumps, and one sludge removal or wasting pump.

The manufacturer claims that the system is capable of reducing BOD and TSS by over 90%. Influent BOD in the range of 250-400 mg/L was consistently reduced to <20 mg/L in finished effluent. Limited data from one system configured for total nitrogen removal also shows significant nitrogen reduction. Inflow total nitrogen of 24.4 mg/L was reduced to 4.9 mg/L in finished effluent.

A basic residential system, which can treat up to 800 gpd, costs $6800 for the module plus $750-1000 in additional installation costs. The distributor estimates a yearly electricity cost to operate the system of about $30 per user. The system requires regular maintenance. Analytical Systems, Inc., the local distributor, offers a maintenance contract at a yearly cost of $240 for residential systems. This includes quarterly maintenance and 24 hour alarm monitoring. The New England version of the Cromaglass system is designed with internal sensors connected to the system control panel so that operations in the system can be remotely monitored and adjusted.

The Cromaglass system has received general use approval from DEP for use in place of a septic tank. It has also received piloting use approval for 80% nitrogen reduction (final effluent <10 mg/L) and for a 67% reduced size leaching facility. A 550 gpd residential Cromaglass system has recently been installed in Cohasset. A unit has also been recently installed in the "99" Restaurant in Yarmouth. There are also numerous Cromaglass installations in Pennsylvania, New York, and Maine. Local distributor of the system is Analytical Systems, Inc., PO Box 720, 11 School St., Sandwich, MA. (508) 833-8856.

Composting Toilets

(From Fact Sheet)

Recently, composting toilets have been promoted as solution to groundwater pollution problems caused by bacteria, viruses, and nutrients such as nitrogen and phosphorus. In addition, the alternative technologies portion of the revised Title 5 which took effect November 10, 1994 has eased the regulatory climate regarding composting toilets significantly. These two factors make it likely that Boards of Health will be asked to consider an increasing number of applications for the use of composting toilets.

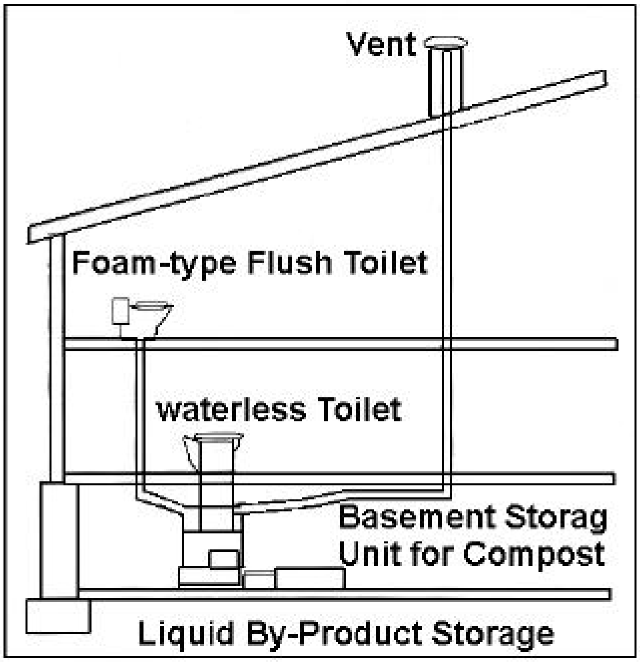


Figure 1. General Schemata of a composting toilet configuration.

Under the 1978 code, composting toilets were allowed with approval by DEP but the owner was required to install an entire Title 5 septic system consisting of a septic tank, D-box and leaching facility to dispose of the dwelling's graywater. The economics of installing a composting toilet plus a Title 5 system, combined with the lengthy approval process, made the installation of composting toilets unattractive except in the most extreme of circumstances.

Under the revised Title 5 composting toilets are certified for remedial use and can also be used for new construction where a system in full compliance with Title 5 could be otherwise be installed. In addition, the new Title 5 has eliminated the requirement for a complete Title 5 system for graywater. Under the new Title 5, for new construction, the leaching facility may be downsized to 60% of the dwelling's design flow and a filter system may be used in place of the septic tank for systems where there is no discharge of garbage grinder waste or liquid by-product from the composter to the graywater system. For remedial use, an existing cesspool may be used as the graywater leaching pit, provided it is not located in groundwater and it meets the effluent loading requirements of Title 5. These changes to the code make the use of composting toilets more economically attractive.

This chapter explores how composting toilets work, end products produced, how well these systems remove nutrients, and offers suggestions to homeowners and Boards of Health who are considering use of these systems.

HOW DO COMPOSTING TOILETS WORK?

Composting toilets are contained waste treatment systems that use natural biological decomposition to convert toilet wastes into water vapor, carbon dioxide, and a stable compost-like end product. The decomposition process is accomplished by aerobic (oxygen-using) bacteria and fungi. The complex population of microorganisms in the composting material make conditions unfavorable for the growth of disease-causing organisms which can be present in human waste. Pathogenic organisms die off or are consumed by the composting organisms as long as the composting process is proceeding normally and has adequate time to work.

In order to produce a thoroughly decomposed compost product, three conditions are essential.

1. The process must remain aerobic. The microorganisms that decompose the waste need oxygen to flourish. Aerobic conditions are maintained by mixing the pile and by controlling moisture.

2. The compost must be maintained at the correct moisture content. If the compost becomes too dry, decomposition will not occur. If the compost is too wet, it will not remain aerobic and decomposition will cease. Humans excrete a much higher volume of liquid than solid each day. This excess liquid must be managed to ensure the composting waste does not become too wet. Excess liquid is managed either by evaporating it off using fans and heater units inside the compost chamber, or is collected at the bottom of the composter unit where it must be disposed of in an acceptable manner. Bulking agents, such as wood shavings, are also commonly added on a regular basis to ensure proper drainage of liquids from the compost and to increase the evaporative surface area.

3. Temperatures must be maintained above 60^{o} F for composting to proceed effectively. At lower temperatures bacterial activity is inhibited and the composting process slows. Temperature can be controlled by maintaining the composting unit at room temperatures above 60^{o} F or by placement of heating units inside the composter unit (units with larger storage volumes can operate at lower temperatures because composting will still proceed slowly and these units have the storage capacity to accommodate a slow composting process.

TYPES OF COMPOSTING TOILETS, PROS AND CONS

There are two types of composting toilets generally available for residential homes. The first type are relatively large, bi-level, watertight containers equipped with a chute that connects the toilet receptacle to the composting unit located in the basement. The composting unit often has an inclined floor where solid waste decomposes and slides to the lower end as new waste enters at the upper end. Excess liquid is drained to the lowest part of the tank where it is either evaporated or collected. Compared to self-contained units (below), bi-level composters have a large compost volume and long retention time. Thus, the composting process is more stable than in smaller units, is better able to cope with peak loads, and can withstand intermittent or seasonal use. Finished compost generally need only be emptied annually or once every several years. The best known bi-level type composter is the Clivus Multrum^{TM}.

The second type of composting toilet are smaller units in which the toilet receptacle and composting tank comprise a single self-contained unit located in the bathroom. These units have traditionally been installed at intermittently-used vacation homes but also have been marketed for year round residential use. The most well known of these units are marketed by BioLet USA, Inc. ("BioLet"), Sun-Mar Corp. ("Sun-Mar"), and SanCor Industries Ltd. ("Envirolet").

Smaller, self-contained units are less expensive, easier to install and can usually be retrofitted into existing dwellings. However, the composting unit is smaller than in bi-level units. Smaller composting units have a shorter residence time with the result that waste may not be fully decomposed before it is discharged, the unit must be emptied more frequently and there is greater potential (and less storage capacity) for liquid accumulation if the unit is overused. Most of these units have liquid collection chambers. If the liquid is not piped to the graywater leaching system, the chamber must be emptied and disposed of properly on a regular basis. Some newer designs incorporate mechanical aeration and heaters so that the composter operates at temperatures of 80-110^{o} F and the composting process proceeds more rapidly. These units are intended to evaporate all excess liquid so that there is no discharge other than finished compost.

Based on owner operation manuals it appears that compost must be removed from these units several times per year. It is also questionable whether these smaller units meet the requirements of Title 5, section 15.289(3)(a), which requires that composting toilets be designed to store composted and compostable solids for at least two years. Recently (March 1997), the BioLet XL (Figure 2) composter (which is equipped with heater and fan units) has received Provisional and Remedial Use approval from DEP specifically exempting the unit from the requirement that it be able to store composted solids for two years. It is unknown whether other units will also be exempted from this requirement in the future.

All small composting units intended for regular, year-round use should be equipped with several devices to ensure that they function properly. They must be equipped with an adjustable thermostat/heater unit so that evaporative capacity can be adjusted based on use of the unit. This device is essential to ensure proper moisture content of the compost and to prevent excess liquid accumulation. Units must be vented and equipped with an automatic fan which acts to aerate the compost, and also prevents excess liquid accumulation. Units should also be equipped with an automatic mixer that is used to increase aeration and speed the decomposition process.

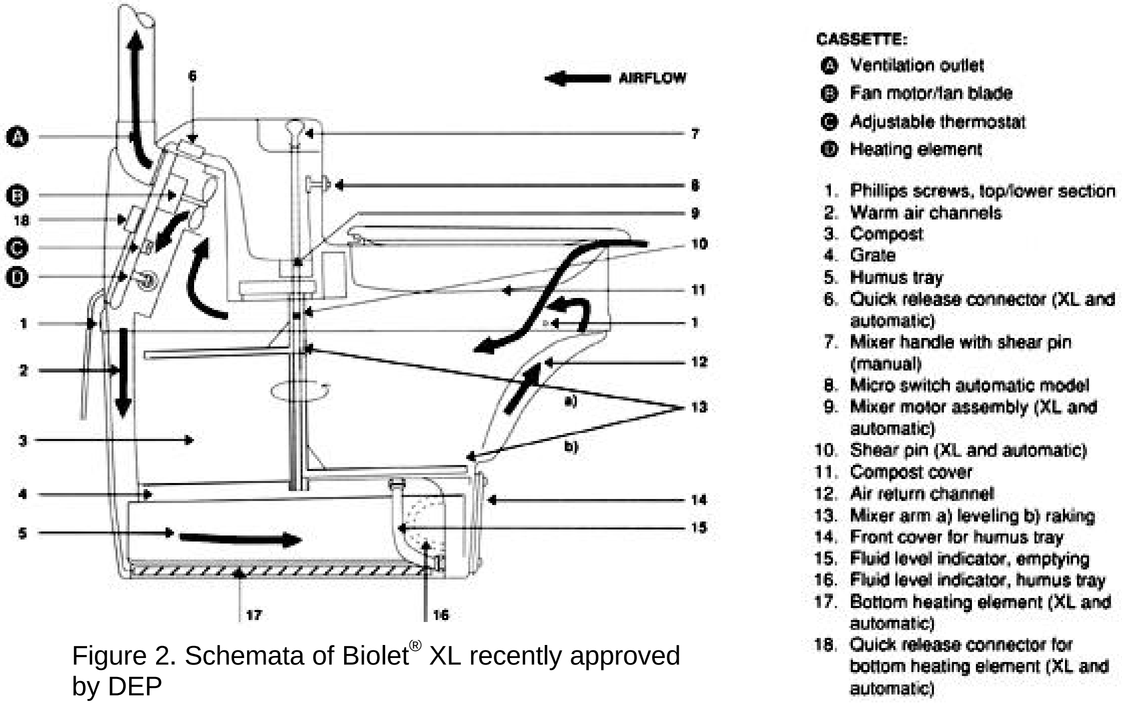
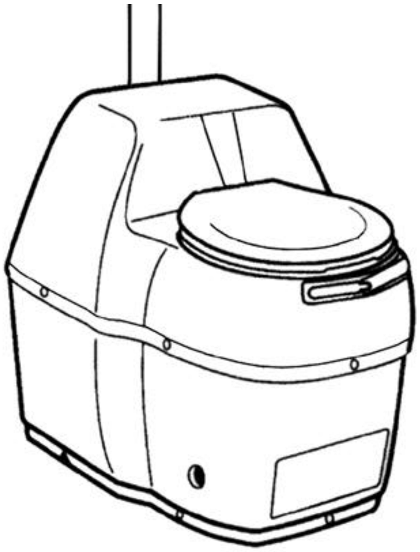


Figure 2. Schemata of Biolet® XL recently approved by DEP

It is important to note that small composter units require a fairly high degree of owner involvement . The owner must monitor the compost carefully for the correct degree of moisture and empty excess liquid as it accumulates. Compost must be disposed of on a regular basis. It should also be noted that these units might not function well in extended power outages when fans, heaters and mechanical aerators become inoperable.

SOLID AND LIQUID END PRODUCTS

All composting units produce a solid compost-like end product and most produce a liquid end product (at least occasionally). These products have the potential to contain pathogens and DEP has strict requirements for their handling and disposal. Household graywater must also be disposed of, generally through conventional Title 5 leaching components. Recently, shallow trench systems with drip-emitter tubing have been proposed for graywater discharge during warmer months when plants can take up the water through their root systems. This type of system must be approved by DEP on a case-by-case basis.



Solid End Products

When solid wastes are completely decomposed, the average person produces 2-3 gal (0.25-0.4 cubic ft.) of compost per year. The compost produced by a Clivus Multrum (the only system for which we have seen data) is approximately 2.5% total nitrogen and has a nitrogen:phosphorus:potassium (N:P:K) ratio of 2.5% N:3.6% P:3.9% K. This compares to garden compost with a typical N:P:K of 2.5:1.5:1.4 or composted sewage sludge at 2.1:2.2:0.3. Nitrogen levels in all are comparable (note that typical lawn and garden fertilizer has an N:P:K of 10:10:10). However, approximately 70% of the nitrogen in the Clivus compost is present as organic nitrogen. This form of nitrogen is bioavailable for uptake by plants and soil microorganisms but will not readily leach to groundwater. As long as the compost is applied in the root zone it can serve as an excellent soil conditioner with minimal nitrogen impact. It should be noted that nitrogen content may potentially be higher in compost produced by small composting toilets. Because these toilets evaporate rather than drain excess liquid, the nitrogen present in urine is likely to become concentrated in the compost.

Phosphorus in the Clivus end-product is somewhat higher than in comparable compost products. However, the majority of the phosphorus is present as organic phosphorus, in which form it is unlikely to leach to groundwater but is bioavailable for uptake by plants.

Pathogenicity of properly decomposed compost appears to be low. Testing performed by Clivus indicates that solid end product in the Clivus composter ranges from 0-35 fecal coliform per gram of compost (septic tank sludge averages 100,000 FC/gram). The majority of bacteria present in the compost are those normally prevalent in soils. The presence of viruses in the compost has not been adequately investigated nor have we seen data for the bacterial content of compost produced by small composting toilets. DEP considers the solid end product to be potentially pathogenic and requires that it be disposed of in a manner such that it cannot be contacted by humans.

The revised Title 5 section 15.289 3(a) requires that solids produced by a composting toilet shall be disposed of either by burial on-site or in another manner and location approved by the Board of Health covered with a minimum of six inches of clean compacted soil, or be disposed of by a licensed septage hauler. If collected by a licensed septage hauler, the solids may be disposed of at a septage treatment plant, bagged and sent to SEMASS, or disposed of at a landfill.

Liquid End Products

Liquid end product routinely accumulates in bi-level composters such as the Clivus Multrum. It may also accumulate periodically in small self-contained composter units, although this usually indicates that the composter is overused or is not working optimally. This liquid end product is primarily urine that has filtered slowly through the composting waste. Limited information available from Clivus Multrum suggests that typical Clivus composter units at residential homes produce 1-2 liters of liquid end product per day.

Urine from healthy individuals does not contain fecal coliform or other bacteria. However, as the urine filters through the compost, it could potentially pick up fecal coliform or other pathogenic bacteria and viruses. Testing performed by Clivus indicates that liquid end product in the Clivus composter shows very low fecal coliform levels: frequently less than 10 FC/100 ml and almost always less than 1000 FC/100 ml. The presence of viruses in the liquid end product, however, has not been adequately investigated. DEP considers the liquid end product to be potentially pathogenic and it must be handled and disposed of in the same manner as conventional sewage.

The revised Title 5, section 15.289(3)(a), which took effect November 10, 1994 requires that if a composting toilet produces a liquid by-product then the liquid must be discharged through a graywater system that includes a septic tank and leaching system, or it must be removed by a licensed septage hauler and disposed of properly (other disposal options such as incorporation in a graywater recycling system will be approved by DEP on a case-by-case basis). All composter units should be installed so that they are accessible to a septage hauler for liquid removal.

It is also important to note that the **liquid end product is very high in nitrogen**. Data from Clivus Multrum indicates that their liquid end product ranges from 2000-10,000 mg total nitrogen per liter (typical septic tank effluent averages 60-90 mg N/L). This is because the liquid end-product is composed primarily of urine which has not been diluted with toilet flush water. The urea in urine is a nitrogenous compound and is the body's main route for excretion of nitrogen. Humans excrete an average of 6 kg of nitrogen annually and 2/3-3/4 of this nitrogen is excreted in urine. Nitrogen in the liquid end product is present almost totally as nitrate that leaches readily to the groundwater. If the liquid end product is disposed of in the septic system the composting toilet is almost no different from a Title 5 septic system in terms of its contribution of nitrogen to groundwater. However, if the liquid end product is reclaimed for re-use and used appropriately it can be excellent fertilizer.

DO COMPOSTING TOILETS QUALIFY AS NUTRIENT REMOVAL SYSTEMS?

How environmentally friendly are composting toilets? Can they be used to alleviate eutrophication problems caused by nitrogen and phosphorus in our coastal waters and ponds?

It is important to recognize that composting toilets do very little to change the quantity of the major nutrients-- nitrogen and phosphorus-- in human waste. Composting toilets can reduce the volume of solid waste by turning it into compost. They can prevent the addition of pathogens to the groundwater by removing human waste from the septic system. They can reduce water consumption. But there is no net loss of nitrogen or phosphorus in a composting toilet; nitrogen and phosphorus are merely repackaged into different forms. In recognition of this fact, DEP has not issued nitrogen removal credits for any composting toilets to date.

At present there are three basic disposal options for wastes produced by composting toilets. Waste can be disposed of on site: compost is buried and liquid waste is disposed of in the graywater septic system. In this case there is no net removal of nitrogen or phosphorus and the composting toilet cannot be considered to meet the goal of nutrient removal. A second disposal option is that the solid and liquid waste is removed periodically by a licensed septage hauler and taken to the local septage treatment plant. In this case, nutrients have been removed off-site which may alleviate local nutrient loading problems. But, unless the septage treatment plant has advanced nutrient removal capabilities, there is still no net loss of nitrogen or phosphorus-- they have merely been exported to have environmental impact elsewhere. A third disposal option is collection of the wastes by a licensed hauler who intends to market the products for use in place of commercial fertilizer. Although there is still no net loss of nutrients, the end products have been substituted for agricultural fertilizer which would have been used anyway, so this solution can be considered to be a net benefit and environmentally friendly. Recent conversations with a representative from Clivus New England indicate that Clivus hopes to develop the capability to remove solid and liquid wastes from all units it sells and installs. Clivus hopes to develop a central collection facility for these wastes and is working to obtain DEP approval for agricultural re-use of these products (however, this has not occurred as of June 1997). If this service does not become available, Boards of Health should recognize that composting toilets do not qualify as nitrogen removal systems.

RECOMMENDATIONS TO BOARDS OF HEALTH WHO WILL BE APPROVING COMPOSTING TOILETS

Where is the installation of composting toilets most appropriate? In repair situations where minimal Title 5 setbacks to drinking water wells and watercourses cannot be met composting toilets may be a good solution since they remove human waste and potential pathogens from the septic system. Composting toilets may also be appropriate for repair situations in tight soils or other situations where water use must be minimized. Composting toilets can also be appropriate to remediate nutrient loading problems as long as adequate provisions are made for appropriate disposal of the end-products.

It is very important for Boards of Health to know that the end-products of the composting toilet will be properly disposed of. A maintenance contract between the owner and a licensed septage hauler for removal of wastes is essential. Because the end-products are potentially pathogenic, a licensed septage hauler should perform maintenance of the system and removal of end-products to reduce exposure of the owner and the public to potential pathogens. Most septage haulers, however, may have limited experience with composting toilets. The Board of Health may wish to require the owner to have an additional contract with the manufacturer or distributor for periodic maintenance to ensure that the system functions properly and that any problems are corrected quickly. For systems which are proposed to remediate nitrogen loading, the Board of Health will also want to make sure that the owner contracts with a septage hauler (or the composting toilet distributor) who agrees to take the end-products to a collection facility where they will be appropriately handled for re-use as fertilizer.

Incinerating Toilets

(From Issue 10)

What do you do when there is no way to repair an onsite system because of restricted space or other severe limitations? Many Boards of Health have recently inquired about alternative toilets that have no discharge. As you recall, in the past we devoted an entire issue to composting toilets. But these toilets, which must be designed to store compost for at least 2 years (310 CMR 15.289(3)(a)) are often larger than can be accommodated in tight situations. In this issue, we feature incinerating toilets (which gives new meaning to the expression "hot stuff"). Incinerating toilets should be considered in situations where all other standard options have been exhausted, and in which there is very limited area available for a leaching facility. Examples of such situations are barrier beaches, tiny lots near the shore, dune shacks, and living units on piers or docks. Approximately 600 electric and a fewer number of gas incinerating toilets have been installed in New England. But, before we get started, let's start with the basics.

WHAT IS AN INCINERATING TOILET?

Figure 2. Schemata of typical gas-fired incinerating toilet installation by Storeburn®

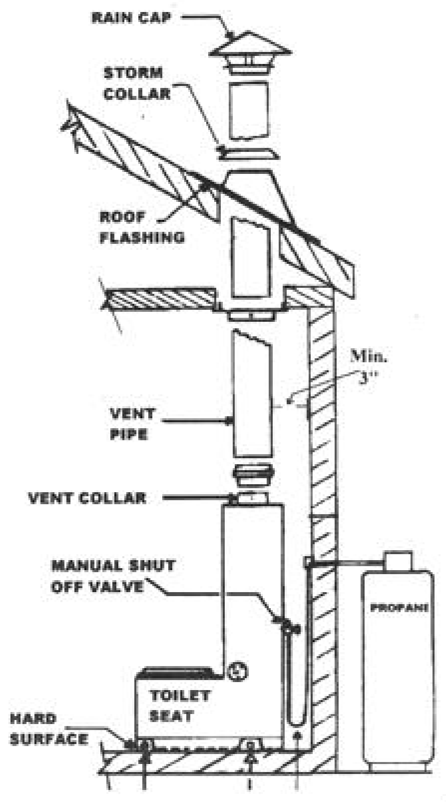
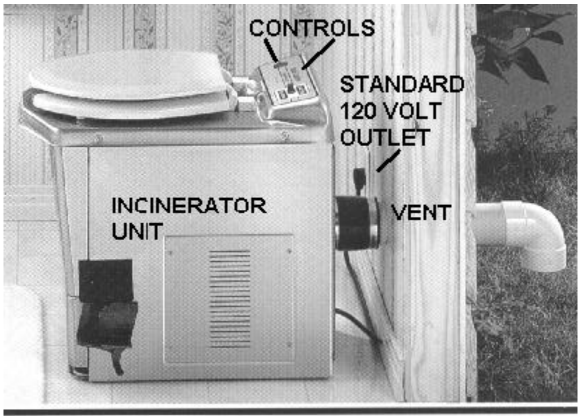


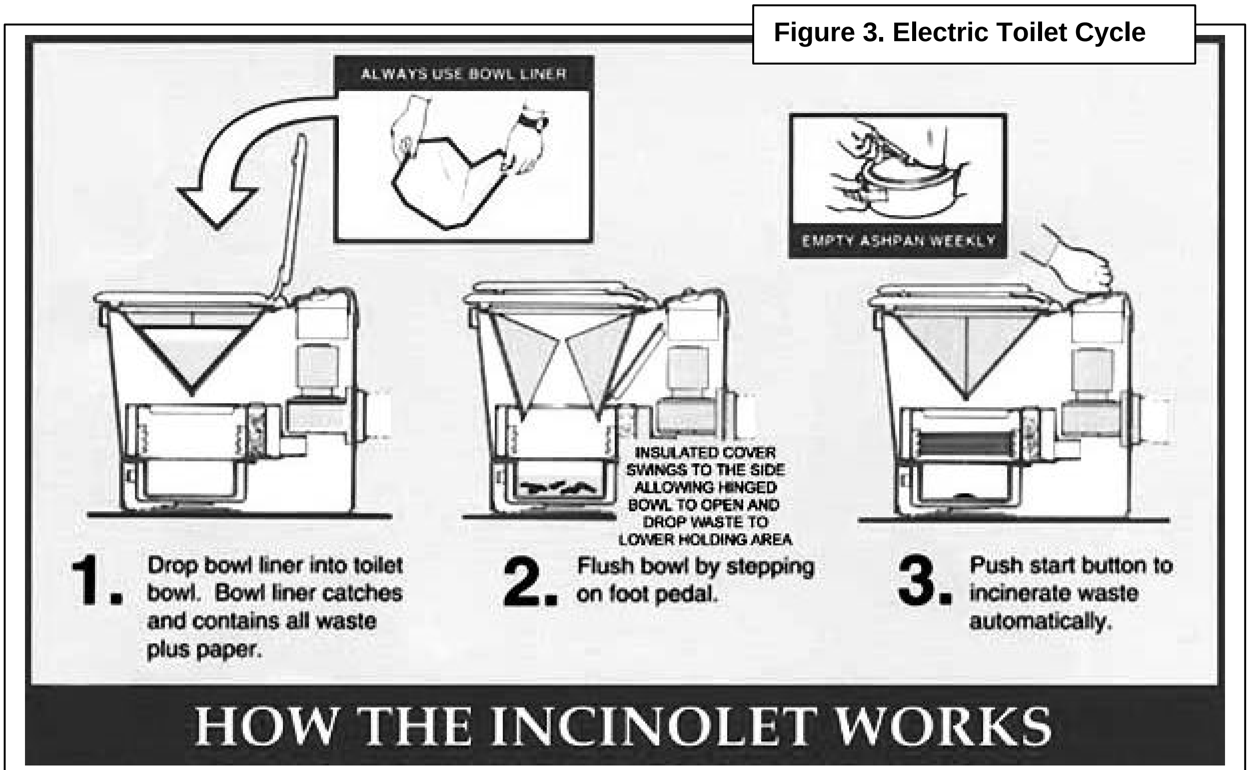
Figure 1. Typical electric toilet installation by Incinolet®



Incinerating toilets are self contained waterless systems that do not require being hooked-up to a sewer system or inground septic system (except to dispose of graywater). They rely on electric power or natural or propane gas to incinerate human waste to sterile clean ash. When properly installed these systems are simple to use, safe, clean and relatively easy to maintain. Figure 1 shows a typical configuration of an electric toilet, and Figure 2 shows a schemata of a typical gas toilet installation. These waterless systems look much like a standard household toilet. Between the gas and electric incinerating toilets there are some mechanical and operational differences, but the overall treatment processes work the same. Both systems accept human waste, both solid and liquid, into a burn chamber. The burn chamber reaches temperatures of 970-1400 ^{o}F and reduces human waste into clean sterile ash.

THE ELECTRIC TOILET

Figure 3. Electric Toilet Cycle



The electric toilet is relatively easy to install. Because the system doesn't require water there is no need for a plumbing connection. Setup involves placing the unit in the desired location, connecting a 3-inch diameter exhaust vent between the rear of the unit and the building's exterior, and plugging the unit into an electrical outlet (120 volts).

The electric toilet requires that a bowl liner be placed into the stainless steel toilet bowl before each use. The liner protects the bowl from human waste and the need for excessive, unpleasant cleaning. Waste is collected into the liner which drops through the hinged bowl into a lower holding/burn area when the foot pedal on the unit is depressed. The lower holding/burn area can accept a maximum of 2-4 "flushes" before incineration is necessary.

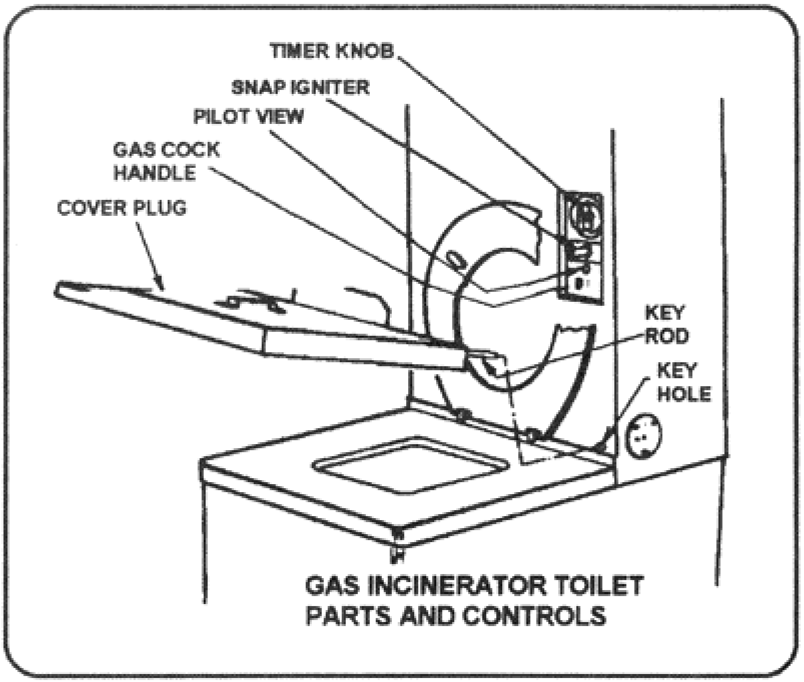
After a "flush", pressing the start button will begin the incineration cycle. Care must be taken that there is no paper or waste product protruding through the hinged bowl. This will prevent any burning or smoke outside of the chamber. The start button activates a heating coil to start the incineration process. The collected waste in the holding area is subjected to heat temperatures of up to 1400 ^{o}F for a pre-selected run time (about one hour). The heat and smoke within the incineration chamber is filtered through an odor control catalyst (much like the one found on a automobile exhaust system) and out the exhaust vent. The systems contains an exhaust blower which continues to extract heat after the heating coil has shut off and until the incineration chamber has cooled down to about 130 ^{o}F. Once the ash pan has cooled down to room temperature the incinerated debris, about a tablespoon, can be discarded. The process in summary is presented in Figure 3.

Over 175 electric toilets have been sold in Massachusetts by INCINOLET. These systems are in use in a number of locations on Cape Cod and the Islands (Bourne, Falmouth, Hyannis, Chatham and Nantucket). The price range of a unit is $1499-$1879, and the system cost about 28 Cents per cycle to operate. People and businesses using these systems indicated that they did not notice a power draw when the toilet was started or in use. Effects of the toilets' electric demand were considered to be not noticeable to slightly noticeable. In two of the five people interviewed, odor from the system was considered a problem because they had not vented the system above their roof line. When their systems were in the incineration cycle they complained that there was a backdraft of odor/smell that was directly attributed to being vented too low. Both persons said that after the system had run for a while that smell became less noticeable. The differences in uses range from one to two incineration's per weekend to a constant running use at a busy boat marina. People interviewed generally felt that the systems are easy to use, worked well and were fairly easy to maintain.

Incinolet is the only manufacturer of electric toilets that we have found. Product information and distribution details can be obtained by contacting RESEARCH PRODUCTS/Blankenship, 2639 Andjon, Dallas, Texas 75220. Phone 1-800-527-5551. WEB SITE http://www.dfw.net/incinolet

NATURAL GAS AND PROPANE INCINERATING TOILETS

Natural Gas and Propane incinerating toilets do not rely on the use of water, plumbing or electricity. These systems can be installed any place where a natural gas or propane source is available. The systems can be temporarily connected to propane gas cylinders like those used on gas grills, or can be directly hooked up to a permanent source of gas. According to the only manufacturer located (Storeburn®), these systems have the ability to accommodate the needs of 8 to 10 workers in an average 8 to 10 hour day or about 6 to 8 persons in a cottage or residence where the daily use would be about 16 hours.



GAS INCINERATOR TOILET PARTS AND CONTROLS

The gas powered incinerating toilets do not contain a toilet bowl. In appearance, they are more like a portable outhouse where the waste is dropped into a holding area/chamber. The holding chamber is located directly below the toilet seat. An aerosol masking foam may be applied after each use to blanket or cover over stored waste deposits. When the system is full or an incineration cycle is ready to begin, a package of anti-foam MK-1 is added to the liquid portion of the waste. **The unit must not be operated without the MK-1**. The toilet seat is lifted and a cover plug is inserted over the chamber opening (this plug acts as the firewall). The timer is set to the recommended setting according to load capacity. A gas cock handle is turned to the pilot position and ignited by pressing a button. Once the pilot light is on the main burner can be activated by turning the gas cock handle to the "ON" position. The system is then in the incineration cycle. Depending on the load capacity the system may burn for 1.5 to 4 hours. The manufacture recommends burning off the loads at times when the toilet will not have to be used such as at the end of the workday or at night. While this may work well for construction sites or weekend camps, it may present convenience problems for full-time living use.

Gas incinerator toilets require more installation considerations than electric toilets. Gas fixtures should be inspected annually for integrity. Venting of gas systems must be observed with the utmost care. An air space must be maintained under the bottom of the unit to assure proper drafting/airflow during an incineration cycle. Rugs and carpets should not be installed under the unit. The unit may not be installed in a airtight room and a provision for "make-up air" must be made. Intake air vents may be necessary if the toilet is to be located in an enclosed room. People who are using the gas systems describe them as being similar to using a port-a-potty without the liquid chemical content. For this review, we interviewed two users, each of whom could be described as using the units limited amounts of time each year (one during the summer on weekends, the other was used for ice fishing 1-3 days per week during the winter). Both systems were run on propane gas. The systems were considered easy to use and to maintain. One person described the system as being the cross between an "outhouse and a gas fireplace" which, functionally speaking isn't too far off.

One interesting system drawback was described as being "psychological". People who are not acclimated to using waterless toilets may be uncomfortable with these systems. Interviews identified that some people had problems with the actual sounds of using a waterless system, the open pit or chamber below the seat, and having to use a covering foam (they didn't care for having to look into the holding chamber). As with electric toilets, venting location is critical for proper odor control. Another recommendation was to have a spare spark igniter on hand in the event that the primary igniter fails. The spark igniter was considered easy to install and being much like the one on your home gas grill. Storburn® units cost in the range of $2,200, not including the necessary venting (approximately $150-$200). In addition, aerosol masking foam and antifoam are continuing costs. We could not estimate the operating costs of the unit based on the limited interviews.

Storburn® has a head office STORBURN INTERNATIONAL, INC., located at 9 Woodslee, Paris, Ontario N3L3T6, Telephone 1-800-876-2286. I also recently found out from a WEB site (www. jademountain. com/comp.html) that the Storburn® factory recently burned down (somewhat ironic) and it is uncertain at this point when or if they will be available again.

WHERE AND WHEN SHOULD INCINERATING TOILETS BE INSTALLED?

If installed in accordance with appropriate codes (gas-fitting, plumbing, electric, building), both gas-fired and electric toilets are permitted in Massachusetts. It is not clear, however, if their use fulfills the requirement of a water closet under the plumbing code. Many of you may remember that the issue of a water- closet requirement prevented the use of composting toilets for years.

Boards of Health in Barnstable County and most areas of the state should only consider permitting the use of incinerator toilets as a replacement for a subsurface sewage system after careful consideration and after all other feasible alternatives have been explored. These units are not specifically referenced in Title 5, and hence there are no specific guidelines for their application. In general, they have been permitted in remedial situations where the living units are seasonal with limited use, and where there is a means for gray water disposal. Most often, graywater disposal in those situations is permitted to an existing facility in similar fashion as has been allowed under 310CMR 15.289(3)(a).

Incinerating toilets find their most ideal application at sites where it is impractical to extend water service or sites which receive very limited use. In the case of gas-fired incinerator toilets, even electrical service is not required. Applications include camps, cabins, fishing shacks, dune shacks, accessory buildings etc. Applications in Falmouth included beach cabanas along Shore Rd. that were heavily damaged during a hurricane.

GRAYWATER AND GRAYWATER DISPOSAL SYSTEMS

(FROM ISSUE 6)

There's been lots of talk recently that wastewater disposal on Cape Cod should evolve toward the use of composting toilets with innovative graywater disposal systems. Graywater is often seen as a benign material that poses a minimal threat to human health and the environment. For this reason, graywater has often been considered a good candidate for various types of reuse or disposal options rather than disposal in a conventional septic system. In this chapter we look at several alternative designs which have been proposed locally for disposal of graywater. We consider the environmental impacts of graywater, and try to balance the cost of alternative disposal options against environmental gains they may provide. We also look at the public health considerations that must be incorporated into any graywater disposal design.

WHAT IS GRAYWATER?

Graywater includes all household wastewater that doesn't come from toilets. This includes wastewater flows from baths/showers, clothes washing, dishwashers and, optionally, kitchen sinks. Toilet wastewater, and often garbage disposal waste, is called blackwater. Graywater comprises about 60% of typical household wastewater flow (Figure 1). Separation of graywater and blackwater is achieved through the use of separate plumbing. Wastewater separation is relatively easy to accomplish in new construction, but can range widely in cost and ease for retrofits of existing dwellings.

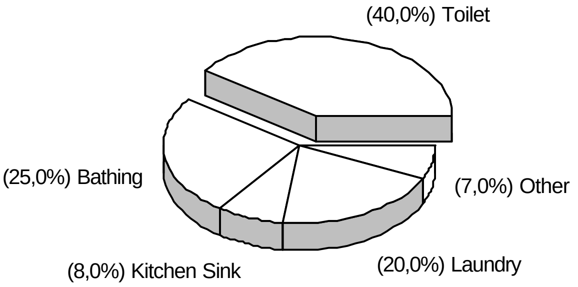


Figure 1. Relative contributions of various sources to household wastewater

BACTERIAL PATHOGENS AND INDICATORS

It is important to recognize that graywater is not always pathogen-free. Under some circumstances graywater may contain more pathogens than are normally found in combined (grey and black) wastewater. This is particularly true in households where a resident is sick or with infants where diapers are routinely laundered.

Numerous pathogenic organisms and microbial indicators have been found in graywater. These include coliform bacteria, fecal coliform including *E. coli,* (including enterotoxigenic strains), fecal streptococci including enterococci, *Salmonella spp*., *Shigella spp*., *Vibrio cholerae*, *Campylobacter jejuni, Yersinia enterocolitica, Aeromonas hydrophila, Legionella pneumophila* and other Legionellaceae, *Mycobacterium tuberculosis* and other mycobacteria, *Staphylococcus aureus* and other staphylococci, *Pseudomonas aeruginosa, Klebsiella pneumoniae, Clostridium perfringens,* enteric viruses including polioviruses, coxsackieviruses, echoviruses, hepatitis virus A, Norwalk virus, caliciviruses, astroviruses, reoviruses, rotaviruses and adenoviruses, and possibly *Giardia* cysts and *Cryptosporidium* oocysts. Many of these organisms are opportunistic pathogens which are more likely to affect older people, young children and individuals who are immuno-compromised (i.e. individuals who are HIV-infected, chronically ill, or are undergoing chemotherapy). Some of these organisms, such as enteric bacteria and viruses and Staphylococcus, are commonly found on the skin or in the oral cavity of humans and are shed routinely during bathing. According to *Management of Small Waste Flows* produced by the

Small Scale Waste Management Project at the University of Wisconsin-Madison (USEPA publication EPA-600/2-78-173, 1978) bacterial indicators are higher in bathing wastewater than in laundry wastewater (Table 1) due to shedding. In comparison, mean concentrations of fecal coliform and fecal streptococci in septic tank effluents are only 10-100x greater than the high values cited for bathing wastewater. In recognition of the public health risks, conventional septic systems are designed to ensure that there is no surface breakout of septic tank effluent. Similarly, surface discharge of graywater, which may contain similar microorganisms at only 1-2 orders of magnitude lower concentration than septic tank effluent, should be controlled. **Graywater should not be applied to the soil surface** in areas where humans or pets have easy access unless the graywater is first disinfected.

Table 1. Fecal coliform and nitrogen in wastewater

Source	**Fecal Coliform per 100 ml**	**Total Nitrogen mg/l**
Toilet	1,000,000	200
Bathing	1,000	20
Kitchen Sink		75
Laundry	100	20
Garbage Disposal		80

OTHER POLLUTANTS

In general graywater is perceived as being relatively clean and low in nutrients or other pollutants. While it is true that graywater is relatively low in nitrogen (most of which is found in toilet wastes), graywater can contain significant amounts of BOD, phosphorus and total suspended solids (Table 2). Biochemical oxygen demand (BOD) in graywater may equal or exceed the BOD content of blackwater. This is primarily because of food waste and grease from kitchen drains. Also due to kitchen sink flows, total suspended solids (TSS) may equal those found in toilet wastes and will far exceed toilet flows when a garbage disposal is used. The phosphorus content of graywater may equal that found in toilet wastes due to the continued use of phosphate-containing detergents. Massachusetts prohibited the sale of phosphate-containing detergents in July 1994, with the exception of detergents used for automatic dishwashers. In a typical residential home these detergents can contribute an amount of phosphorus equal to that found in toilet wastes.

Table 2. Wastewater Pollutant Contributions in grams per person per day.

Source	**BOD (5 day)**	**TSS**	**Total Nit.**	**Total Phos.**
Toilet	6.9-24	13-37	4.1-17	0.6-1.6
Garbage Disposal	11-31	16-44	0.2-0.9	0.1
Greywater	25-39	11-23	1.1-2.0	2.2-3.4

GENERAL CONSIDERATIONS FOR DESIGN OF GRAYWATER SYSTEMS

Graywater must be treated before discharge. The conventional treatment method, a septic tank large enough to provide at least a two-day retention time, allows grease to cool, solidify and float to the top. This is particularly important when kitchen wastes are part of the graywater flow. Also, longer retention times allow fine solid materials suspended in the wastewater to sink to the bottom of the tank.

The 1995 Title 5 allows the use of a filter in place of a septic tank when only graywater is being disposed of. Several proprietary filters are available. For example, Clivus New England Inc. markets a three-stage aerobic intermittent sand filter. Graywater first flows through a mesh filter which catches large solids and then through a layer of coarse-grained sand. It next passes through a screen filter and into a proprietary media where biological oxidation occurs. Biomat is expected to form at each filter stage to attenuate bacteria and trap solids. There is limited information on the effectiveness, longevity and maintenance requirements of this and many residential graywater filters. In designing or evaluating any graywater filter it is important to recognize that the grease and kitchen solids found in graywater may clog filters. The BOD and nutrients present will promote bacterial growth that may also clog filters and necessitate frequent cleaning.

Increased longevity of the leaching system and reduced maintenance of the grey water system may be achieved if the kitchen sink is not plumbed into the graywater system. Garbage disposals should be strongly discouraged as they can stress even a conventional septic system and will provide an overwhelmingly high solids load to a system designed to handle only graywater. If a garbage disposal is installed it should be plumbed to the blackwater system.

WHAT INNOVATIVE DESIGNS ARE AVAILABLE FOR DISPOSAL OF GRAYWATER?

Reduced Size Conventional Leaching Facility

The simplest way to dispose of graywater is a conventional soil absorption facility. Under the 1995 Title 5, if graywater alone is discharged the leaching facility may be sized for 60% of the building's design flow. A septic tank is not required for disposal of graywater only. A filter system specifically approved by DEP may be used in place of the septic tank as long as no garbage disposal waste or liquid waste from a composting toilet enters the graywater disposal system. A conventional leaching facility will generally be the lowest cost alternative for disposal of graywater, averaging $2000-3000 to install. How thoroughly does a conventional leaching field treat graywater? Properly sited leaching facilities with adequate separation to groundwater will act efficiently to remove bacteria and many viruses through simple filtration and adsorption. Filtration will also provide almost complete removal of total suspended solids. Substantial reductions in BOD should also be achieved as the effluent passes through the biomat that surrounds the leach field. The amount of phosphorus removal will largely depend on the soil type in which the leaching system is installed: sands generally have less capacity to attenuate phosphorus while clay or silt soils may attenuate significant amounts of phosphorus. Conventional leaching facilities also provide recharge to the groundwater that other innovative designs may not.

Shallow Drip Soil Absorption Systems

A relatively new design for disposal of graywater is the shallow drip soil absorption system. This system has been used in agriculture for many years to irrigate crops using a network of shallow underground pipes fed by a pump. It delivers water at a controlled rate for uptake in the root zone minimizing percolation of water. When used to dispose of graywater the drip system also has the advantage of using the treatment capability of the surrounding soil to further treat the graywater. Nutrient and organic constituents in the effluent are removed by vegetation or are degraded by microorganisms as effluent moves through the soil. Thus, the quality of effluent treatment is directly linked to the soil and site characteristics such as soil permeability, drainage, slope, and depth to limiting conditions such as bedrock or groundwater.

How it works: graywater first enters the pre-treatment unit (a septic tank, sand filter, etc.) and flows by gravity to a pump chamber or dosing tank. The collected effluent is periodically pumped under pressure to the subsurface drip field. The drip field consists of parallel rows of polyethylene tubing with drip emitter holes (pinhole size) at about two-foot intervals. The emitters distribute the effluent at a slow and controlled rate to a large surface area of soil. This allows the system to operate over long periods without saturating the surrounding soil. It also allows the system to be installed at a shallow depth, usually 6 to 18 inches below the surface. An additional benefit of the design is the use of treated effluent to water shrubbery and gardens.

The drip emitter design is often modified in northern climates where the ground freezes solidly in winter. In addition to the drip tubing these designs incorporate a deeper leaching trench of pressure-dosed perforated PVC pipe laid in a gravel bed 24-36 inches below the ground surface. Piping from the dosing tank leads to a series of valves so that graywater flow can be shunted to either the drip irrigation bed or the deeper leaching trench depending on season of the year.

A potential problem with drip emitter systems is biological and chemical clogging of filters, drip lines, and emitters. Chemical clogging can be caused by a high solids content in the effluent. Residual solids may deposit in the emitter holes if water evaporates out of it between doses, and the resulting buildup of solids around the drip hole may eventually slow the system's rate of flow. Similarly, salts deposited by evaporation of effluent may also form deposits around the emitter holes and slow flow. Clogging can generally be avoided if the system is flushed routinely (2-4 times per year). This can be accomplished by designing the system so that a garden hose can be connected and high pressure water forced through the system. Alternatively, use of a sand filter to pretreat the effluent before it flows to the drip tubing may eliminate the need for flushing. The sand filter greatly reduces the total suspended solids and BOD content of the effluent that should minimize biological clogging of the system.

A typical household drip disposal system costs about $4000-6000 to install. While this is more expensive than a conventional disposal system it can compare favorably with other alternative disposal options, especially where there are limiting site conditions such as slowly permeable soils or high groundwater. An additional cost of operating the system is the cost of hiring a certified operator who will oversee and periodically flush the system.

Where may the installation of shallow drip disposal systems be most appropriate? The goal of a drip system is to make maximum use of soil treatment capabilities. Drip disposal systems may work well in sandy soils where the effluent is applied in the finer textured topsoil layer where it receives better filtration than it would otherwise receive in the underlying sand. Also, effluent filters through the soil more slowly than in a conventional system, providing better attenuation of pollutants in soils with a fast percolation rate. Because of the slow rate at which effluent is applied, drip systems may also be suitable for marginally usable clay or silt soils where conventional systems will not work.

Other Shallow Disposal Systems

Another type of shallow disposal system utilizes 1 inch perforated PVC pipe laid at 6-18 inches below the surface. The system design is similar to the drip system, including a pretreatment unit and dosing chamber which pressure doses the disposal field. The irrigation bed can be laid at a depth of 6 inches directly in the topsoil, or at a depth of 18 inches in the underlying soil (with or without gravel surrounding the pipe). Many systems use pipe installed at both 6 and 18 inches for summer and winter use, respectively.

As with the drip system, treatment of the effluent is accomplished by biological processes in the surrounding soil and by the fact that effluent is applied at a slow rate. Thus, installation of this type of system is appropriate in situations similar to those discussed for drip systems. The system may also be better able to handle solids than a drip system because the holes in the PVC pipe are larger than those in the drip tubing and are thus less likely to clog.

Closed Evapotranspiration Systems

Yet another strategy for disposal of graywater is to drain the filtered graywater to a specially constructed sealed garden unit. In this type of system graywater is distributed either by pressure or gravity through a series of pipes laid in a gravel bed within a lined excavation. A layer of sand is laid over the gravel and planted with selected plants. The sand acts as a wick to draw the water to the surface for evaporation while the plants take up the graywater by their roots, utilize the nutrients for growth, and transpire the water as vapor. Designs of this type are constructed as no-discharge units where theoretically all water is disposed of by evapotranspiration. The units may be located either indoors in a greenhouse-type design or outdoors in constructed beds.

Several design considerations are key to the success of these units. Firstly, success of the system depends on the evaporation rate of the bed exceeding the rate of effluent loading plus precipitation. This may necessitate a very low effluent loading rate, especially for beds constructed outdoors. Secondly, the sand or gravel used to construct the bed must be large grained enough to ensure that the bed drains thoroughly and remains aerobic. If more water is received than can be evaporated, or if the bed drains poorly, the soil pore space will remain saturated and will tend to go anaerobic causing the plants to die. In addition, if the bed drains poorly there is the chance that graywater will come to the soil surface that is not desirable (and also not legal under Massachusetts health regulations). Evaporative capacity of the bed will vary with both climate (solar radiation, temperature, humidity, wind speed, precipitation) and with the type of plants selected for use. If the bed is constructed outdoors it will likely function at reduced or minimal capacity in winter when precipitation exceeds evaporation. In this case, an alternative provision such as leaching trenches or a tight tank should be made for graywater disposal.

A potential long-term problem with evapotranspiration systems is the buildup of salts left in the soil by the effluent as it evaporates. With time salt concentration may increase to the point where it is harmful to vegetation. Plants in the beds may also have to be fertilized occasionally since graywater usually contains little nitrogen.

Cost of installation can vary widely largely based on whether the unit is constructed indoors or out. The costs of household units consisting of a lined bed constructed outdoors can vary widely. One recently installed in Wellfleet cost approximately $ 5,000 (Figure 2). If a tight tank must be installed to handle excess flow this will present an additional cost to install and pump. Because evapotranspiration systems produce zero discharge (and are usually coupled with a composting toilet which should also create zero discharge), these systems are most appropriate where soil conditions are limiting (high groundwater, impermeable soils) or where inadequate setbacks to wells or watercourses exist.

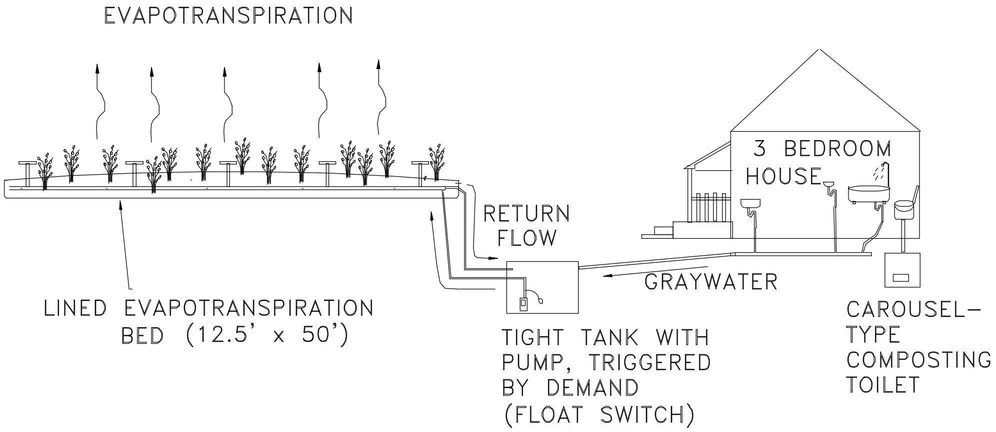


Figure 2. Schemata of Graywater Evapotranspiration Bed Installed in Wellfleet

It should be recognized that evapotranspiration units are somewhat experimental and often require some trial and error with dosing rate or plant types used before they function properly. Because there is no standard design for evapotranspiration units all designs should be viewed with scrutiny before approval. These designs must also be approved on a case-by-case basis by DEP before installation. A detailed design module entitled *Onsite Wastewater Disposal Evapotranspiration and Evapotranspiration Absorption Systems* produced by National Small Flows Clearinghouse is available by request to our department for Boards of Health or engineers who may be considering designs for systems of this type.

SCENARIOS WHERE INNOVATIVE GRAYWATER SYSTEMS MAY BE PROPOSED

What are the most likely scenarios that Boards of Health will encounter where innovative graywater disposal systems are proposed? Where may innovative graywater designs provide a good solution to wastewater disposal?

Where an existing septic system is failing hydraulically, it may be possible to install composting toilets and allow graywater to flow to the existing cesspool or septic system. In repair situations (remedial use), DEP will allow graywater to be disposed of in an existing cesspool under the following conditions: a composting toilet is used for human waste; there is no discharge of garbage grinder waste or liquid waste from the composter; the cesspool is pumped and cleaned; the cesspool is not located in groundwater; the cesspool meets the design criteria of 310 CMR 15.253 (design criteria for pits, galleries, or chambers); and the effluent loading requirements of Title 5 are met. Because the total volume of water is reduced and because graywater contributes a lower solids and BOD load than combined wastewater the existing septic system may be able to hydraulically function if it receives only graywater. A number of systems of this type have been approved by DEP elsewhere in Massachusetts and seem to be functioning well. This appears to be a cost effective way for homeowners to deal with some hydraulically failing systems.

Where an existing septic system has been deemed to have failed because of insufficient setbacks to wetlands or watercourses, use of the existing septic system or an innovative shallow trench design for graywater only may also be appropriate. Setbacks to watercourses are determined primarily to ensure that pathogens are removed by soil filtration before wastewater intercepts a watercourse. Removal of the toilet waste to a composting toilet (or tight tank) will remove the majority of pathogens from the wastewater. It will also remove most of the nitrogen and approximately half of the BOD and phosphorus thereby reducing nutrient loading to the water body. Use of a shallow trench to further treat graywater may provide additional reduction in pathogens, BOD, and phosphorus loading.

A more difficult scenario is presented by septic systems that are deemed failed because of inadequate separation to groundwater. Obviously, the best solution in this scenario is to create a mounded leaching system so that adequate separation can be maintained. Where small lot size prevents this, compromise must be made. Title 5 allows a reduction to a two foot separation distance to groundwater for combined (grey and black) wastewater for local upgrade approvals when no other option for siting the leaching system exists (310 CMR 15.415). In this extreme case, it seems much preferable to remove the toilet wastes (to composter or tight tank) and allow only graywater to be disposed of with reduced separation to groundwater. Use of a shallow trench system, preferably located in topsoil, to further treat graywater may provide additional reduction in pathogens, and secondarily in BOD and phosphorus loading. Or, use of a closed evapotranspiration bed and composter will provide a zero-discharge system.

A similar scenario is presented by existing septic systems that have inadequate setbacks to drinking wells. The 1995 Title 5 allows a reduction to a 50 foot setback to a well for a combined wastewater disposal system. In the extreme case where a 50 foot setback cannot be met, or where hydrogeologic conditions warrant further protection, a closed graywater evapotranspiration bed and toilet composter zero-discharge system may be the best solution.

A last (and more pleasant) scenario is presented by the home owner who wishes to voluntarily install a composting toilet and graywater disposal system in the belief that these will benefit the environment. The beliefs that motivate this choice range from a desire to conserve water in general to a desire to protect our embayments and ponds from nutrient loading and to a desire to protect groundwater from various drinking water pollutants. How well will use of a composting toilet and graywater system achieve these goals? Installation of a composting toilet can reduce household water use by up to 40% (although this can also be achieved by using ultra low flush toilets). Removal of toilet waste from household wastewater will also significantly reduce pathogen and nitrogen loading to the disposal system (however, see discussion in the section on Composting Toilets as to if and when these systems truly qualify as nitrogen removal systems). Total phosphorus discharge may also be halved. This can result in significant improvements in groundwater quality beneath the disposal system.

SOME CONCLUDING THOUGHTS

Careful consideration needs to be given to the issue of whether the cost of construction of an innovative graywater disposal system equals the benefit received. Conventional leaching systems that meet the requirements of Title 5 probably renovate graywater fairly completely with the possible exception of removing phosphorus. Shallow trench systems, which generally cost at least twice as much to install, may provide additional treatment in summer months when effluent is applied in the topsoil but may not provide any treatment beyond that of a conventional system in winter months when effluent is applied in the deeper soil layers. Closed evapotranspiration systems must be very large to function effectively in our climate, are costly to build, and probably are cost effective only in the most extreme circumstances when other disposal alternatives are limited.

Innovative graywater systems have been proposed, and are often marketed, as a solution to protect our groundwater. Proponents make the argument that innovative graywater disposal will protect groundwater from pollution by pathogens and nutrients. They also propose that use of innovative graywater systems will benefit groundwater in other ways. Firstly, if composting toilets are used less household water will be needed, resulting in less groundwater withdrawal. Secondly, if the groundwater withdrawn for household use is later disposed of as relatively clean graywater, it is argued that the groundwater has been recharged with clean, rather than polluted, water. Is the amount of water recharged from a graywater disposal system significant and does it provide a net benefit to groundwater?

Most of the graywater disposal systems discussed in this document are designed to rely largely on evaporation and evapotranspiration to dispose of graywater. This implies that these systems produce little to no recharge of graywater to the groundwater. Even if all the graywater discharged is recharged to groundwater, it still makes up only a tiny percentage of the total annual recharge to groundwater. Cape Cod receives about 40 inches of rain per year, about 18 inches of which is recharged to the groundwater (the rest being lost to evapotranspiration by natural plant communities during summer months). This results in a net recharge to the groundwater of about 488,800 gallons of water per acre per year (1.5 ft. of rain x 43,560 sf/acre= 65,340 ft^3/acre X 7.481 gal/ft^3= 488,808 gal/acre). A graywater disposal system, which produces a net contribution to groundwater of 100 gal/acre/day, results in 3650 gal/acre/year recharge to the groundwater. This constitutes less than 1% of the total recharge to the groundwater over that land surface.

Recently, proponents of composting toilets and innovative graywater systems have urged DEP and the state legislature to allow the use of graywater disposal systems (in repair situations) with minimal setbacks: a 1 foot vertical separation to groundwater and/or bedrock, a 5 foot horizontal separation to surface waters, wetlands and other environmentally sensitive areas, and a 50 foot horizontal separation to surface drinking waters. Given the information we know about graywater, and the present lack of information about the presence or absence of viruses in graywater, we believe that these setbacks are not sufficiently restrictive to protect public health.

PROGRESS REPORT - GRAYWATER RECYCLING SEPTIC SYSTEM

Rarely a week goes by when we don't receive an inquiry on how our wastewater recycling garden is working. Many of you know that under the Wellfleet Harbor Project, our Department installed a graywater recycling "garden" in a situation where no discharge on the lot was allowed. The crude schemata of the system is presented in Figure 1. Under guidance from a consulting company, the system was designed to collect the graywater from the house into a tight tank. Graywater was subsequently pumped into a lined planter bed (50' x 12.5') when the float switch was activated. The water level in the planter bed was prevented from rising too high by a relief system that allowed it to drain back to the tight tank. The environmental consultant supplied the design specifications and oversaw the construction of the system.

If the old expression is true that "you learn best from your mistakes" we are now much wiser from what we learned here. Foremost, we learned that the loading rate to this system grossly exceeded the ability of the system to remove the water through evapotranspiration. In our system, the three bedroom home (assumed 330 gallons/day), served by a composting toilet (assumed reduction in flow of 40%), would require a graywater system that would be able to handle 198 gallons/day. The graywater bed constructed provides approximately 625 ft^2 of application area. We now understand this application rate to the garden is far greater than what can be evapotranspired. This system received very little use in the first year of installation, yet had consistent difficulty in eliminating the rainwater, and the limited input from the house.

A second design flaw in our system was the system of effluent distribution to the bed. In the scenario where the bed is full, and it rains while graywater from the house is also entering the pump chamber, the pump continually runs, pumping "against the tide". This constant wetting and production of saturated conditions is not conducive to evapotranspiration in the bed. We believe that this problem could be rectified by using a timer-controlled dosing, with adequate storage design to accommodate flows from the house and reasonable rain events. Even during drier periods, the timed-dosed system would provide better air movement through the system as opposed to the demand-dosed system that only provides large pulses of water during peak usage.

In addition, we now understand that better precautions to shed rainwater off of the top of the bed could have been employed, such as a loam and a seeded crown. "Dust mulching", that phenomena purportedly responsible for sealing the sand and making it less permeable, was totally inadequate in this situation. After taking before and after-rainfall measurements in the bed after the system had been in for one year indicated that nearly all the rain permeates the crown of the system. The Wellfleet system is presently shut down until we can make the necessary adjustments. In the spring, we will also be introducing additional plantings and continuing to monitor the ability of this system to evapotranspire graywater.

A frank assessment of this technology suggests that significant refinements are necessary before it should find widespread use in Massachusetts. There are only a few, examples of its satisfactory performance in the state. Design guidance from reputable firms with long-standing experience is difficult to find. Although this technology, perhaps above all others, tempts the imagination with thoughts that our wastewater can be renovated, immediately recycled to produce greenery, and negate the need for any discharge, there are still many factors that must be considered. In particular, total evapotranspiration systems must be highly managed by individuals who understand the complexities of the soil systems used, the tolerances of the plants employed, and the characteristics of the wastewater applied. In situations, such as the one in Wellfleet, where there is a recycling of graywater, long term issues of salt buildup and plant tolerances must be adequately addressed. While not discounting the eventual development and use of this technology in Barnstable County, we would caution individuals contemplating <u>total</u> evapotranspiration beds to consult individuals with proven track records. Less critical, but still requiring significant expertise, are those situations where shallow soil horizons are used to receive graywater and make some use of the evapotranspirative qualities of overlying vegetation.

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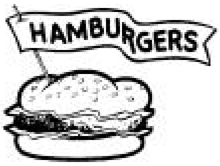
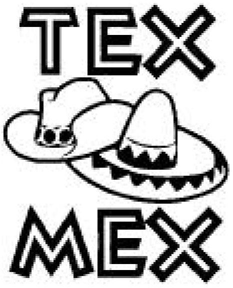
Grease and Oil in Restaurant Wastewater

(From Issue 7)





Wastewater from restaurants and other commercial food service facilities differs significantly from residential wastewater. In addition to higher surge volumes during busy periods, and generally higher temperatures, restaurant wastewater is typically higher in strength than residential wastewater. This is due to higher levels of oil, grease and foods which cause a higher biochemical oxygen demand (BOD). Oil and grease frequently cause problems for both on site sewage disposal systems and public sewer systems. The problem occurs when oil and grease liquefy at the high water temperatures used to wash dishes and later solidify in sewer lines or sensitive soil interfaces in the leaching facilities of onsite systems. The problem is exacerbated when highly efficient detergents are used to emulsify the oil and grease, keeping them in suspension until they enter the leaching field. Although conventional grease traps are supposed to prevent grease from entering the septic tank or sewer line, high grease loads, emulsified grease, and surge wastewater loads often cause grease to bypass the grease trap and enter the leach field.

When grease reaches the soil absorption system it can physically clog the soil pores preventing both water infiltration and the free transfer of oxygen necessary to digest waste. The high BOD present in grease also promotes excessive bacterial growth which causes the formation of a thick anaerobic biomat that has less ability to actually treat the waste. The result is premature failure of the soil absorption system. Data suggests that if soil absorption systems at restaurants are to function in the long term, design modifications must be made which take into account the much higher wastewater strength, flow variations, and oil and grease constituents found in restaurant wastewater.

UNDERSTANDING OIL IN WATER

Oil in water can be present in four basic forms: free oil, mechanically emulsified oil, chemically emulsified oil, and dissolved oil. The majority of oil and grease found in restaurant waste is **free oil** which will rise to the surface of the water in which it is contained. All conventional grease traps and grease recovery devices discussed here are basically designed to recover free oil by allowing it to coalesce. The liquid oil can then be collected by skimming the water surface (grease recovery devices) or the oil can be allowed to congeal on the water surface for later collection (conventional grease traps). A second form of oil in water is **mechanically emulsified oil**. This is caused by agitating a free oil and water mixture to the point where it breaks the oil up into very small droplets (10-20 microns). High water temperatures and use of liquid vegetable oils promote mechanically emulsified oil. Mechanical oil emulsions will separate by themselves given enough time, but without sufficient time for separation to occur (i.e. if the grease trap is too small or there is excessive surge water loading) these oils can be carried over into the leach field. Oil and grease may also become **chemically emulsified**, primarily through the use of detergents and other alkalis. Chemically emulsified oil particles are very small (<1 micron) and do not rise to the surface of the water regardless of how much time is allowed. Chemically emulsified oils can be removed by specially designed pre-treatment units, however these are generally sized for higher volume industrial uses, and we are unaware any small-scale units which are available. Chemically emulsified oil may be a significant portion of the total grease in food service wastewater and is quite likely to be carried through the septic system to the leaching facility. The best strategy for dealing with chemically emulsified oil in restaurant wastewater seems to be preventing it from becoming emulsified in the first place. This can be done by using detergents which promote rapid oil/water separation. Lastly, oil may be present as **dissolved oil** in which case it is no longer present as discrete particles. Oil generally becomes dissolved in water through the use of degreasing compounds which are soluble in both oil and water (hence their ability to be degreasers). Since many degreasers are chlorinated solvents or other prohibitively strong chemicals we recommend that these compounds not be used, hence eliminating the problem of dissolved oil.

WASTEWATER CHARACTERISTICS

Several studies characterizing restaurant wastewater were conducted at the Universities of Washington and Wisconsin in the 1980's. Results from both studies are shown in Table 1, along with results for typical domestic wastewater. The Washington study analyzed **raw** (no pretreatment for grease removal) restaurant wastewater for oil and grease, BOD, and total suspended solids (TSS). The Wisconsin study characterized **pretreated** septic tank effluent (STE) from 12 full service restaurants. All systems included **1 or more septic tanks for pretreatment** and 8 of the 12 restaurants also had indoor grease interceptors. All but one of the restaurants served full dinners and many served lunch. However, 5 of the 12 restaurants received substantial amounts of non-restaurant wastewater (2 were located at large restaurant/motel complexes and 3 were at golf clubs). The data shown in Table 1 for the 6 selected restaurants refer to the six restaurants which served full dinners but did not receive wastewater from other sources such as showers or locker rooms. As shown, pretreatment by simple septic tank/grease traps results in a significant reduction in oil and grease, BOD, and TSS compared to raw restaurant wastewater, although these constituents are by no means reduced to levels of residential wastewater by these measures.

Table 1.

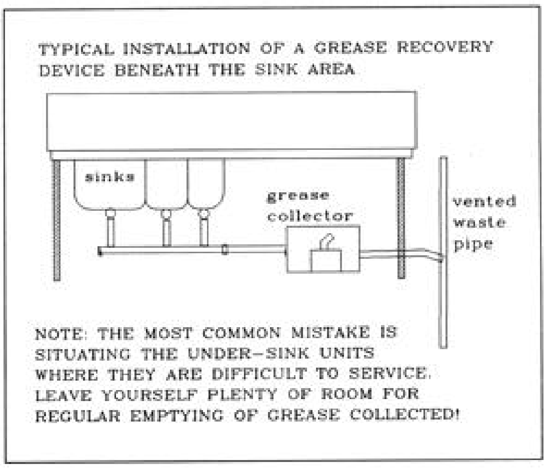
Type of Wastewater	**BOD mg/l**	**Oil and Grease mg/l**	**TSS mg/l**
Raw restaurant wastewater (Washington Study)	1000-2000	100-300	300-625
Pretreated restaurant wastewater (Wisconsin Study- 12 restaurants)	101-880 avg = 365	24-144 avg = 63	
Pretreated restaurant wastewater (Wisconsin Study-6 selected full-service restaurants)	245-880 avg = 506	40-144 avg = 83	65-372 avg = 177
Domestic Wastewater	100-400 avg < 230	16-65	100-350

The Wisconsin study concluded that preventing oil and grease from getting into the septic system was the best way to prevent problems. Other solutions recommended to protect soil absorption systems included: plumb kitchen waste separately since it contains the majority of grease, BOD and TSS; install grease traps or grease recovery devices; provide biological pretreatment of wastewater before its discharge to the soil absorption system; properly size soil absorption systems based on wastewater strength; and educate restaurant personnel in kitchen practices which minimize discharge of grease to the plumbing. Each of these strategies is discussed below.

OPTIONS FOR REMOVING OIL AND GREASE FROM WASTEWATER

Grease Interceptors (Under the Sink Grease Traps)

Grease interceptors are typically small, ranging from five to fifteen gallons of liquid capacity (Figure 1). Because of their small capacity, traps connected to a multiple compartment sink or dishwasher can easily be filled within a week's time. Once filled, hot water running through the interceptor will dissolve the grease and a steady state (grease coming in, equals grease going out)

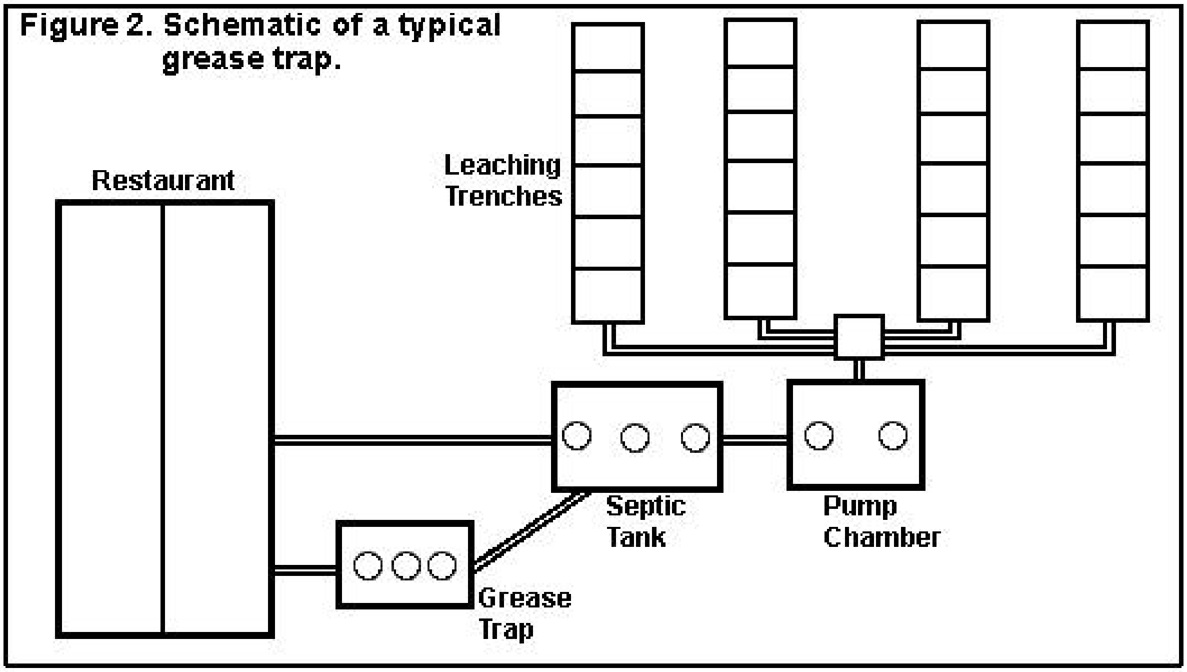


will be reached. A further problem is that cleaning these interceptors is a smelly messy job with the result that they are rarely cleaned. It is generally recognized that grease interceptors **alone** are not particularly effective in preventing grease from entering the septic system leachfield.

Conventional In-Ground Grease Traps

Title 5 requires that grease traps be installed to handle kitchen flows at restaurants, nursing homes, schools, hospitals and other facilities from which quantities of grease can be expected to be discharged. Grease traps must have a minimum depth of four feet, a minimum capacity of 1000 gallons and sufficient capacity to provide a 24-hour detention period for wastewater flows. Warm greasy liquid wastes from the kitchen enter the tank and mix with the cooler liquid in the tank causing the grease to separate and congeal. As long as the mixing is not turbulent, the warmer liquid rises and the cooler liquid, from which the grease has been separated, settles and is carried out to the leach field. Sizing the tank to provide at least a 24 hour retention time is supposed to ensure sufficient cooling time for the grease to separate from the water. In some cases, however, this designed tank volume may not be large enough, especially if the kitchen produces very greasy wastes or there are periods of surge loading (several hours at dinner, high weekends loads, etc.). An important note is that when cleaning the grease trap only the grease layer should be removed. It is optimal not reduce the liquid volume available for cooling the greasy wastes entering the tank. A schematic of grease trap placement is presented in Figure 2.

Figure 2. Schematic of a typical grease trap.



Even under the best of conditions, in-ground grease traps remove only a percentage of the total grease and BOD. Comparison of raw vs. in-ground grease trap treated wastewater in the Washington and Wisconsin studies discussed above suggests that **grease traps are capable of removing up to 50-60% of oil and grease and 50-80% of BOD and TSS (Table 1)**.

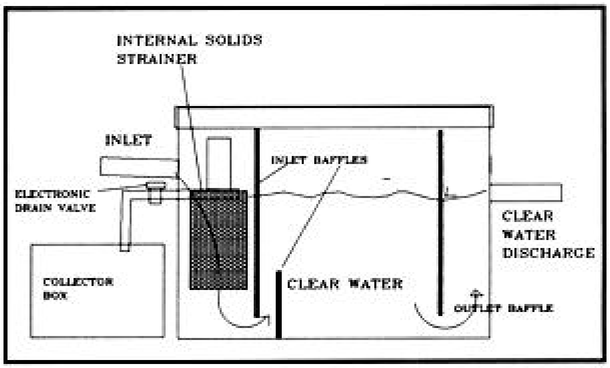
Restaurant Type (with 1,000 gal grease trap)	**Grease influent (mg/l)**
Fried Chicken	120-6500
Chinese	76-1300
Mexican	96-1040
Country Club	130-706

The **Zabel® Filter** is a product designed to improve the efficiency of grease traps. The filter is installed in the grease trap in place of the standard outlet baffle. It is intended to prevent most grease and food products from leaving the grease trap. Information provided by Zabel on the grease removal efficiency of its filter installed in a 1000 gallon in-ground grease trap is presented in Table 2. The filter cartridge must be serviced regularly; if not serviced it will continue to stop the outflow of grease but will eventually shut down the flow of effluent from the tank. Restaurant personnel can clean the filter themselves into a waste grease container or can save the mature cartridges for a septic service company to clean. The cost of a Zabel filter including cartridge is $185.00 plus installation; replacement cartridges cost $86.00 each.

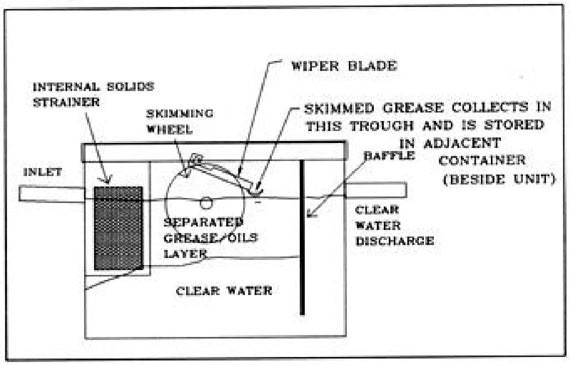
GREASE RECOVERY DEVICES

Grease recovery devices (GRDs) are designed to intercept, trap and remove floating (free) grease and oil in kitchen waste before it leaves the building. They are typically installed in the kitchen to receive wastewater from dishwashers and/or three-compartment sinks. The basic design consists of a baffled box which receives warm kitchen wastewater. Grease and oil separate and rise to the water surface where it is mechanically skimmed or allowed to drain off the top of the water and flow to a recovery chamber.

In the design used by the **Atlas® Systems Grease Recovery Device** (Figure 3) the water enters the box and is forced downward by an inlet baffle. The grease separates as it passes through the perforated baffle. The separated grease rises to the surface and is contained by the outlet baffle. A heating unit in the box maintains water temperature at 120° C so that all grease will remain in liquid form which ensures maximal grease/oil separation. As grease builds up in the retention area it signals a sensor which opens the grease draw-off valve. Grease then flows to the grease collector box for reclamation. The purchase cost of the device is approximately $3500.00. Many of these are presently in use in Dennis and Barnstable and testimony on their performance generally is quite positive.



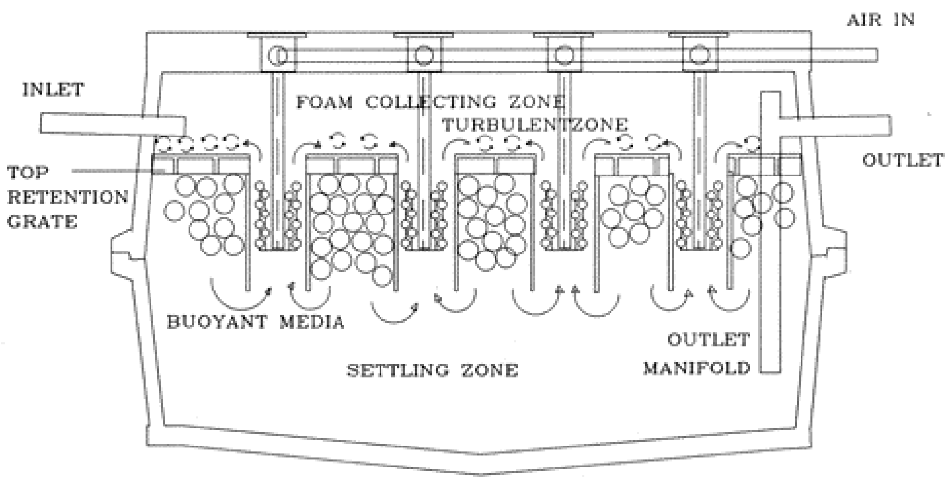
The **Big Dipper®** (Figure 4) grease recovery device operates on a similar design which allows grease to rise to the water surface. In the "dipper" design, a surface is exposed to the grease\water mixture and subsequently wiped to an oil conveyance/collector pipe. The pipe lets the grease flow to a storage unit beside the skimmer. The cost of this unit is $2500-$3500 depending on size. It is important to note that all of these grease recovery devices are designed for and are only capable of removing free grease and oil that is floating on top of water. They are not effective in removing emulsified grease (i.e. grease held in suspension by detergents).



BIOLOGICAL PRE-TREATMENT

Another option for preventing oil and grease from entering the soil absorption system is the use of biological pretreatment to breakdown and digest the grease. Biological pre-treatment units are basically small secondary sewage treatment systems designed to aerobically digest BOD and grease in wastewater. **The Nibbler®** (Figure 5) is a pretreatment system specifically designed to treat high strength commercial wastewater. The Nibbler is purported to reduce wastewater strength (BOD) by approximately 90%, making the wastewater roughly equivalent to domestic septic tank effluent and therefore suitable for disposal in a soil absorption system. It is specifically marketed to restaurants, schools, supermarkets, and other food processing establishments. The Nibbler is an aerobic digester which uses up-flow aeration. The Nibbler unit is comprised of buoyant media held in place just below the liquid surface by pods of molded plastic which resemble milk crates. The buoyant media provides a large surface area to support growth of the microbial population which digests the grease. An airblower forces air through airtubes located in the center of each pod. This creates an aerated liquor which turbulently circulates through the buoyant media. The continual aeration and turbulence introduce oxygen which supports microbial growth and digestion of the waste. Turbulence also promotes

Figure 5. The Nibbler®



biological sloughing from the media. The air blower is the only mechanical portion of the system and is housed in a separate vault. **A typical Nibbler installation consists of an inground grease trap followed by a surge tank followed by the Nibbler unit then a clarifier tank before the leach field**. The Nibbler unit itself is installed in a 1750-2000 gallon single compartment concrete tank with the top exposed at ground level. The surge tank supplies flow to the Nibbler unit at a constant rate and compensates for the surge water loads common at restaurants. The Nibbler is sized based on average daily flow and biological loading and each unit ideally should receive no more than 6.5 lb. BOD per day and 1100 gpd wastewater. Multiple units can be installed if flow and wastewater strength warrant. A mandatory contract for quarterly maintenance and monitoring is required by the Stuth Company which sells the unit. A single Nibbler unit including the buoyant media pods and airblower costs about $7000.00 installed.

In some cases, recirculating sand filters can be another option for pretreatment of wastewater before discharge. The sand filter acts as a biological treatment unit to digest grease and food waste and thereby lower BOD. A properly sized, efficiently operating sand filter should be capable of reducing BOD to levels equivalent to untreated domestic wastewater. However, there are several design constraints which must be taken into consideration. BOD in wastewater entering the sand filter should not exceed 720 mg/L (most restaurant kitchen waste should be able to meet this limit if it passes through a grease trap first). Assuming a BOD of 720 mg/L, the sand filter can accept a hydraulic load of about 1.6 gpd/sf (loading rate(gpd/sf) = 1150/BOD per DEP RSF design guidance). To accommodate such a low loading rate, the sand filter must have a very large surface area. For example, the wastewater from only the kitchen flow of a 100 seat restaurant (100 seats X 15 gal/seat=1500 gal) would require about 940 sf of sand filter surface (surface area(sf) of filter bed=design flow/loading rate; SA=1500/1.6=937 sf). It is apparent that RSFs are feasible only for restaurants with low volume flows or where lots of space is available for construction of the sand filter.

Other small package systems which utilize extended aeration may also provide a degree wastewater treatment although they are not specifically designed for this purpose. As long as these units are not overloaded with grease to the point of clogging they are able to significantly reduce BOD and TSS and over time will usually develop a bacterial population that is capable of digesting a significant portion of oil and grease. For example, the Bioclere® unit has been installed at a number of supermarkets where it is effectively reducing total grease in finished effluent. Typical influent to the Bioclere unit (which has already passed through a septic tank) contains 40 mg/L grease and finished effluent contains 7 mg/L. It is not known how effectively the Bioclere unit would function with the higher levels of oil and grease in restaurant waste.

BACTERIA AND ENZYMES

Most Boards of Health have heard manufacturers and sales representatives make wonderful claims for these products. However, there have been few well designed studies and there is no conclusive evidence about the effectiveness of specific bacterial or enzyme products for treating grease in either grease traps or in the leaching field.

OTHER STRATEGIES FOR REDUCING GREASE OVERLOADING AND SEPTIC SYSTEM FAILURE

Restaurant Kitchen Practices

Possibly the most cost effective way of protecting the septic system from the effects of grease is to change kitchen practices. Dishwashing personnel should be trained to thoroughly scrape plates and cookware to remove all food waste, especially cooking oils and creamy sauces and gravies which are high in grease, before rinsing dishes. Higher water temperatures and higher water flow rates promote mechanical emulsification of oil. Low temperature (sanitizing rinse) dishwashers may assist in keeping oil from being emulsified and may promote more rapid separation of free oil and grease in the grease trap. Use of shortening in place of liquid vegetable oil also promotes more complete separation of grease, since shortenings solidify at room temperature and liquid oils do not. Another strategy to improve grease separation in the grease trap is the use of specially formulated dishwashing and general cleaning detergents which promote rapid oil/water separation. These special detergents are formulated to create an unstable oil-water emulsion which rapidly breaks down releasing the grease so it can rise to the water surface. One manufacturer is Allied Enterprises Inc. of Norfolk, Virginia. Restaurant supply wholesalers may know of other sources to purchase these products.

Correct sizing and loading rate for soil absorption system

The Wisconsin study cited above was prompted by the hydraulic failure of a number of restaurants' soil absorption systems (SAS). Several of these systems failed hydraulically within months of being put into operation despite the fact that no errors in system design or construction could be found. The Wisconsin study found that most of the restaurants' SAS's had been designed using guidelines for domestic systems with only minor modifications for organic loading, problem wastewater constituents and water flow variations. The Wisconsin study examined SAS's at 12 restaurants for efficiency of operation and for evidence of failure such as ponding within the SAS. The study found that these systems were dosed at hydraulic loading rates of 0.08-0.9 gpd/sf. Of the 12 systems, 5 were performing badly and 3 of the 5 had surface effluent breakout. The study results suggested that hydraulic loadings higher than 0.4 gpd/sf may be too high for long-term successful operation of the SAS where higher organic loads are expected.

The Wisconsin study also concluded that, more important than the hydraulic loading of the SAS , is the mass loading of selected wastewater constituents. High mass loading of organic matter and suspended solids may result in clogging of the SAS. The mass organic load applied to the SAS's of all 12 restaurants studied varied from 8.8 to 99.8 lb/BOD/acre/day. Four of the 5 systems whose SAS's were performing poorly were found to have organic loading rates greater than 40 lb/BOD/acre/day. This organic loading rate is more than twice as high as that typically applied to SAS's for domestic septic tank effluent.

The study also found that SAS design may be important. All 5 of the poorly performing SAS's in the study were bed designs. One trench system seen performed well even at very high hydraulic and organic mass loading rates. The study suggests that trench designs perform better than bed designs, possibly because trench designs offer greater infiltrative surface area and greater aeration.

The study concluded that for SAS bed designs installed in sandy soils (perc rate <10 min/inch) maximum application rates in the range of 0.70 gpd/sf hydraulic load, 40 lbs.BOD/acre/day, and 15 lb TSS/acre/day were appropriate. Higher mass loadings may possibly be successfully applied to SAS's using shallow narrow trench designs.

Septic System Maintenance

Because restaurant wastewater contains significantly higher levels of organic matter, solids and grease than residential wastewater it is possible that sludge accumulation in restaurant septic tanks may occur more rapidly than in household units. This may require the septic tank to be pumped more frequently than the every 2-3 years recommended for residential tanks. It may be prudent to pump the sludge and scum from restaurant septic tanks quarterly during their initial period of operation; after the rate of solids accumulation is known the pumping schedule can be adjusted as needed.

SOURCES OF INFORMATION ON PRODUCTS

THE FOLLOWING FLIER WAS CREATED FOR BOARDS OF HEALTH TO DISTRIBUTE TO RESTAURANT OWNERS, AND IS REPRODUCED HERE. IF YOU WOULD LIKE A CAMERA-COPY FOR DUPLICATING ON YOUR OWN LETTERHEAD, CONTACT BARNSTABLE COUNTY DEPARTMENT OF HEALTH AND THE ENVIRONMENT.

Big Dipper
Thermaco, Inc.
Diversified Sales Co. (localrep)
20 Spring Valley Rd.
Woodbridge, CT 06525
(203)-393-2020

The Nibbler
Stuth Company, Inc.
28620 Maple Valley
Rd.SE
Maple Valley, WA 9803
(800) 221-3159

Zabel filter
Northeast Filtration (local rep)
169 Camelot Dr.
Plymouth, MA 02360
(617)-585-2753

DETERGENTS
Allied Enterprises
814 West 45th St.
PO BOX 6159
Norfolk, VA 23508
(804) 489-8282

Atlas Systems Inc.
PO Box 747
Rockland, MA 02370
(617)-878-0334

RESTAURANT OWNERS

12 SIMPLE WAYS TO PROTECT
YOUR SEPTIC SYSTEM

Restaurant kitchen wastewater usually contains high levels of food waste and grease. If grease or food solids reach your leaching field they can permanently damage the field so that it no longer functions to dispose of wastewater. This leads to costly leaching field repairs. You can help protect your leach field by following these simple procedures.

Changing kitchen practices is a low cost but very effective way of protecting your septic system from the effects of grease:

1. **Train dishwashing personnel to thoroughly scrape plates and cookware** to remove all food waste, especially cooking oils and creamy sauces and gravies which are high in grease, before rinsing dishes. Thorough scraping of dishes will prevent the majority of grease in your waste stream from entering your septic system.

2. **Consider installing a grease recovery device (grease skimmer).** These devices, installed in the kitchen, are designed to trap and remove floating grease from wastewater before it leaves the building. Wastewater enters the trap where grease rises and is continually skimmed off the water surface. The grease then flows to a collection chamber for recovery. Grease recovery devices can remove a large percentage of grease in wastewater.

3. **Practice water conservation.** Restaurant kitchens produce surge water flows during mealtime dishwashing periods. Surge water loads push wastewater through the grease trap too rapidly for grease to separate. Water conservation helps prevent surge loading.

4. **Low temperature (sanitizing rinse) dishwashers** may assist oil and grease to separate out in the grease trap. High water temperatures cause grease to become emulsified. Emulsified grease does not separate out in a grease trap and may be carried over into your leaching field. Check with your dishwasher manufacturer to see if your machine can be used as a low temperature sanitizing rinse dishwasher.

5. **Look for special dishwashing and general cleaning detergents that promote rapid oil/water separation.** These detergents are formulated to release oil quickly so that it can rise to the water surface instead of remaining emulsified.

6. **Use proper concentrations of solvents, cleaners and disinfectants**. Solvents and cleaners can cause grease to become emulsified and be carried past the grease trap to the leach field. Excess use of disinfectants reduces bacterial action in the septic system which in turn reduces treatment of wastewater.

7. **Use shortening in place of liquid vegetable oil**. Shortenings solidify at room temperature while liquid oils do not. Shortening oils will separate out more rapidly and thoroughly in a grease trap while liquid vegetable oils are more likely to be carried over into the leach field.

Make sure your septic system and grease trap are serviced regularly:

8. **Pump grease trap quarterly (unless local regulations require more frequent pumping).** Leaving grease in the grease trap too long causes it to harden which makes it very difficult to pump out.

9. **Leave most of the liquid in the grease trap when it is pumped.** Only the layer of grease which accumulates on the water surface should be removed when the trap is pumped. Leave the underlying liquid to act as a reservoir of water so that new grease entering the trap can cool rapidly and solidify.

10. **Pump septic tank frequently to prevent buildup and carryover of solids**. Because restaurant wastewater contains high levels of solid food waste sludge may accumulate rapidly. If too much sludge accumulates solids can be carried over into the leach field and damage it.

If you are upgrading your septic system:

11. **Consider installing a larger in-ground grease trap, or a series of grease traps.**
A standard grease trap has a 1000 gallon capacity. This volume is intended to provide wastewater with a long enough residence time so that it can cool and grease can separate and solidify. If the grease trap receives high surge volumes of water and/or high temperature water there may not be enough time for wastewater to cool and grease to separate. A larger grease trap, or a number of smaller grease traps in series, will compensate for this problem by providing a longer residence time. The longer the residence time of the wastewater, the better the grease removal.

12. **If you are replacing your leaching system, consider installing leaching trenches instead of a leaching bed design.** Leaching trenches provide more oxygen to the wastewater entering the leaching field. This promotes bacterial growth which breaks down the wastewater and helps to prevent clogging of the leaching field.

.Effluent and Vent Filters

(From Issue 10)

Effluent filters are devices that can be affixed to outlets of septic tank and grease trap as pictured below (Figure 1). The filter is a primary screening barrier designed to reduce the volume of solids passing out of the tank and through to the soil absorption system (SAS). If you were to pour unfiltered effluent from a septic tank into a clear glass (yuk!) and hold it up to the light, you would see that there are many fine particles of organic matter (and some inorganic material like fine grit) floating around. These particles, some barely visible to the human eye (and some that aren't) are referred to as suspended solids. The measure of their abundance is referred to as Total Suspended Solids or TSS. Average TSS values from residences is 60-120 PPM. When these particles pass out of the septic tank into the leachfield, they settle in the small spaces between the soil, reducing the capacity of the soil to drain away the effluent. Given enough time, and aerobic (free exchange of oxygen) conditions, many of these organic particles break down into the basic components of water, carbon dioxide, and other simpler compounds. If too much of this organic matter is deposited on the soil interface however, the soil spaces clog and ponding of the effluent in the leachfield occurs. This results in anaerobic (no oxygen) conditions which further impedes the complete breakdown of wastes.

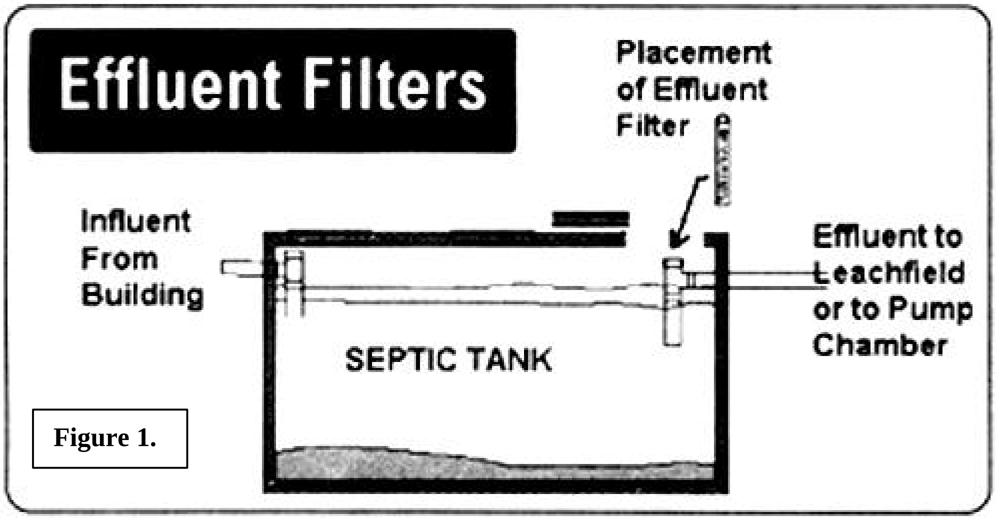


Figure 1.

By retaining more of the suspended solids in the septic tank and reducing the amount of organic material that "demands" oxygen to breakdown (technically this is called reducing the Biochemical Oxygen Demand or BOD) that passes into the leachfield, the performance of the leachfield in breaking down waste can be improved. This results in a longer leachfield "life". The goal of a good effluent filter is to do exactly this - prevent the passage of suspended organic and inorganic materials into the leachfield, while not impeding the flow of effluent to the point where it backs up into the building. Effluent filters perform this function by providing either screens or directing the flow across areas where the suspended material becomes trapped or settles out.

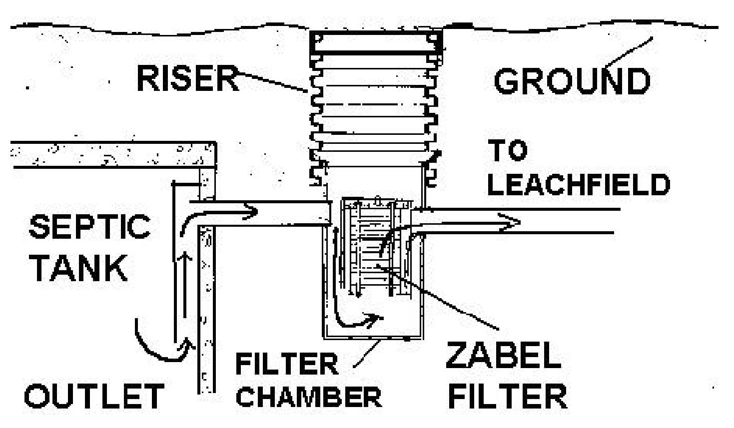


Figure 2. Effluent filter located outside the septic tank or grease trap in a separate filter chamber**.**

The effluent filter is most commonly a simple device that fits into the discharge tee of a septic tank as pictured here. For a household, a 4-inch diameter filter is used. New tanks can easily accommodate the filter installation, while previously installed tanks can often be retrofitted. In some cases, where an effluent filter is desired but a precast baffle is in place (as opposed to a PVC sanitary tee) it may be necessary to install a filter chamber along the outlet pipe between the tank and D-box. This is illustrated in Figure 2.

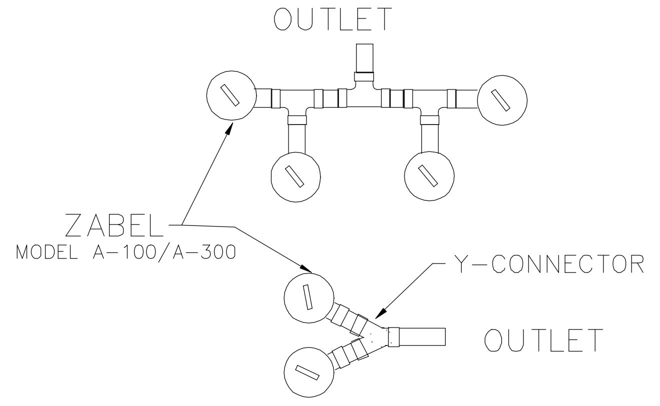
In addition to acting as a filter, the effluent screen acts as a substrate, on which organisms can grow and digest the trapped waste. The mass of organisms and trapped waste eventually grows on the filter to the point where the weight causes it to slough off into the tank below and undergo subsequent anaerobic digestion.

There are a variety of filter sizes to accommodate facilities' daily design flows. Large systems may require multiple filters going through a manifold arrangement in order to meet the daily flow rate as shown in top view in Figure 3 By utilizing a manifold configuration with the appropriate filter size(s) any tank or grease trap's daily design flow can be accommodated.

HOW WELL DO EFFLUENT FILTERS WORK?

Until recently, most of the information on the effectiveness of effluent filters has been intuitive and anecdotal. Promotional literature from one of the approved effluent filter companies, Orenco Systems Incorporated (OSI) reported that the average TSS from their filter is less than 30 PPM. TSS levels in unfiltered effluent range from 60-120 PPM. Zabel Environmental Technology's model A100 (a larger residential unit) in tests performed by Tennessee Technological University averaged a 49% reduction in TSS and a 32% reduction in BOD. The actual performance in any particular situation will depend on a number of factors, the most important of which is daily flow. Both Zabel and OSI provide sizing-criteria charts so that you can size your filter appropriately.

Figure 3. Illustration of a manifold arrangement of effluent filters used to accommodate large daily flows (illustration modified from promotional material from Zabel Environmental Technology).



State Approvals

As you might guess, if it has to do with the septic system, it needs a state approval. All three companies shown in Figure 4 have approvals for various models of effluent filters that they market. In general, the approvals have the following conditions:

1) Prior to sale of the product, the owner of the system shall be provided with a copy of the approval and its conditions by the distributor of the filter.

2) Prior to installation in an existing system, the owner shall obtain approval from the Board of Health for the proposed modification of the system.

3) All septic tanks in which the effluent filter is to be installed must have a 18" or 20" manhole over the outlet tee (approval letters between the three manufacturers differ because of the date

and code under which they were approved). In addition, both the inlet and outlet manhole covers must clearly note the system is equipped with the filter.

4) The filter outlet tee must extend below the flowline in accordance with a provided table (See Title 5 Section 15.227).

5) A Septage Handler, licensed by the local board of health must service the filter and pump the septic tank regularly - at least once every two years.
Boards of Health should have copies of the approval letters for those models of filters that have approvals.

The popularity of effluent filters will undoubtedly increase in coming years. Since many of the upgrades to "old code" systems will allow the continuance of the 1000 gallon tank, many installers may rightfully advise owners regarding this relatively inexpensive accessory that can prolong the life of a leachfield. There are at least two towns in Massachusetts that require effluent filters for new construction and repairs (Pembroke and Duxbury). Their reasoning for the requirement is the belief that the filters help to save the SAS.

The servicing of effluent filters is relatively simple. The filter should be removed from its basket and rinsed down while being held over the tank opening. Care should be taken not to spray the filter growth onto surfaces that might be contacted by the unprotected person. In addition, the person servicing the filter should protect themselves from backspray. Washing filters off may become problematic in winter months when garden hoses are usually not connected. Servicing of the filter should only be performed by a licensed septic pumper familiar with the cleaning precautions and procedures.

OTHER FILTER APPLICATIONS

Effluent filters are not totally restricted to gravity-fed septic systems. Filtered or screened pump vaults are fairly common nationwide and are gaining popularity in Massachusetts. Screened pump vaults (Figure 5.) as their name implies, are simply protective screened cages that surround the effluent pumps used in pumped-dosed or pressure-dosed systems. They are extremely important in situations where effluent is pumped directly from the septic tank (however this is a rarer situation in Massachusetts), as opposed to the more common situation where the

Zabel Environmental Technology
10409 Watterson Trail
Jeffersontown, KY 40299
Phone: 800-221-5742

Orenco Systems Inc.
814 Airway Avenue
Sutherlin, Oregon 97479
Phone 503-459-4449

Flowlink Mfg. Company
7225 Pacific Ave., SE
Olympia, Washington 98503
Phone 1-800-982-5393

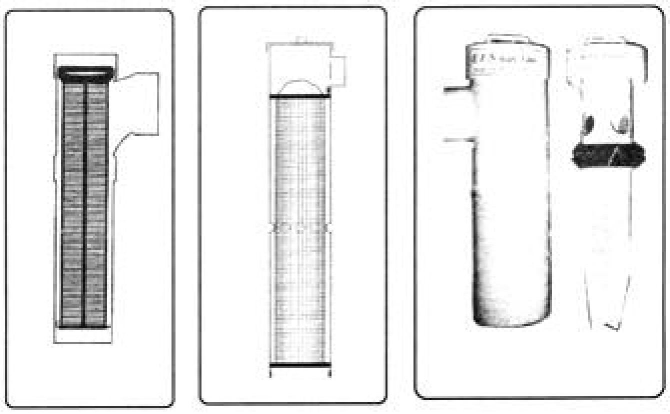
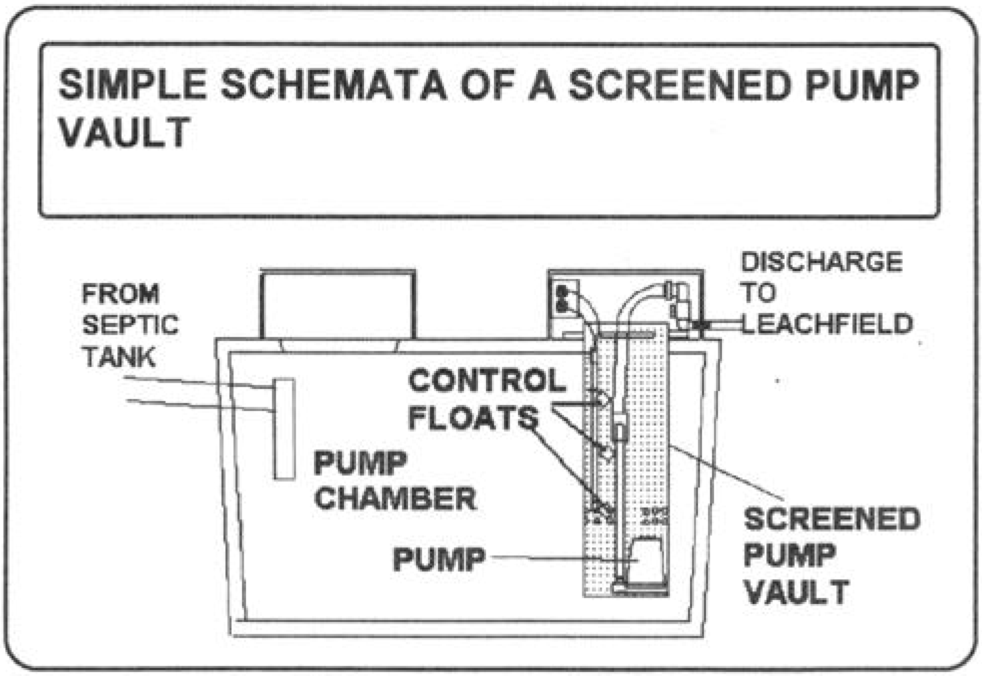


Figure 4. Popular models of effluent filters from each of the three manufacturers having approval in Massachusetts. In order Zabel Model A1800, Orenco Systems Incorporated various models, Flowlink Mfg. Company Model EFS 12.

Figure 5. Simple schemata of a screened pump vault.



effluent is pumped from a separate pump chamber. The screen type used in screened pump vaults is very similar to that used in effluent filters.

In addition to screening at the pump, the installation of an effluent filter between septic tank and the pump chamber of dosed or pressure-dosed systems is certainly a prudent measure that can prevent passage of solids to the pump chamber (and ultimately the leachfield). This is particularly true for larger or commercial systems. In commercial installations, the filter may act as one more line of defense against the introduction of grease into the leachfield.

MORE ACCESSORIES - CHARCOAL FILTERS

The restriction on placing leaching systems deeper than 3 feet below grade or beneath driveways has caused a number of requests for variances from these provisions. This is particularly true in repair situations where the elevation of existing plumbing is difficult and expensive to change. To

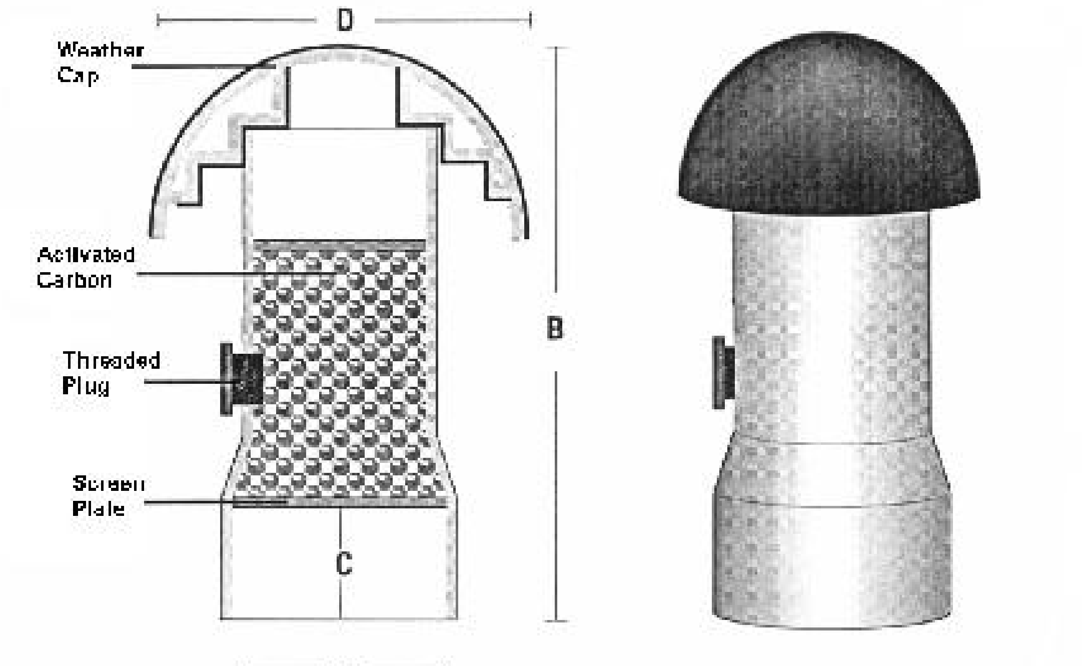


Figure 6.

compensate for this deficiency, a number of system designers propose venting the leachfield. This is generally quite simple if you have enough room between the vent and a susceptible nose. Sometimes however, that telltale odor arrives just in time to cause complaint and ruin the appetite. To address this issue, charcoal filters that fit on the end of the vent are often used. These filters can be homemade or manufactured. The key ingredient is activated charcoal. Below is illustrated a commercially produced filter. Figure 6 is taken from promotional literature of OSI, but, as you can see, the principle is pretty simple. The essential characteristics of a good vent filter are that it does not restrict the airflow (hence the charcoal should not be compacted in the filter), it should be secure from weather, and it should be reasonably accessible for maintenance. As far as we know, no special permits are required for this accessory, nor are charcoal filters required on any venting system. They are really for that rare case when odor becomes a problem.

Final Note on Vent Filters

Our program has also received information on a product called *SweetStack II*®. This device apparently fits on the ***roof vent*** of your septic system. The manufacturer describes the "operating technologies" as "thermal absorption, conduction and convection; venturi and a three stage tirbulator". A description on how the system works is presented in the promotional literature that can be obtained by contacting the address below. Again, in the rare event that vent odor from a roof vent becomes problematic, this product purportedly helps. It is marketed by Cape Cod Envirotech, P.O. Box 821, Denmark, Maine 04022 (Tel. 207-452-2842).

Board of Health Concerns
Relative to the Use of Alternative Systems

Boards of Health, as the local approving authority, have ultimate say over where, and how many (if any) alternative treatment systems will be installed in their town. While alternative systems' ability to provide enhanced wastewater treatment and solve wastewater disposal problems make them attractive, Boards of Health should be aware of several issues of concern relative to the use of these systems.

INSPECTION, MAINTENANCE, AND MONITORING

The first of these concerns is alternative onsite septic systems require regular inspection and maintenance to ensure that they function effectively. DEP, in its approval of most systems (except gravelless drain systems and those systems not employing pumps), requires that each system be under a maintenance contract with a certified wastewater operator at all times. The wastewater operator is responsible for any required water quality monitoring as well as any maintenance necessary to keep the unit operating effectively. Most distributors of alternative systems provide an initial contract between the homeowner and a wastewater operator who is trained to operate and maintain that system. These maintenance contracts usually cost from two to three hundred dollars a year (this may be more depending on the system), not including cost of water quality monitoring. It is in the property owner's interest to maintain this contract to prolong the life of their septic system. But, some property owners may not understand how necessary maintenance is to the proper functioning and longevity of their system. In some instances, for financial reasons, property owners may choose not to keep the maintenance contract in effect. Boards of Health have little guarantee that property owners will maintain maintenance contracts over the long term. The only way to ensure that maintenance contracts are kept in effect, and that systems are monitored when required, is for Boards of Health to have a structured tracking program for alternative systems. This type of tracking program can require significant commitment of personnel time. Boards of Health should plan for this commitment before they allow widespread use of alternative systems.

To simplify tracking the monitoring and maintenance of alternative systems , Boards of Health may wish to allow their installation only within specified wastewater management districts. This consolidates physical placement of the systems. And, when installed in a wastewater management district, it may be possible to have one certified operator be responsible for the operation of all systems.

During their approval process, Boards of Health should also check to make sure that the monitoring requirements imposed on a system by DEP are sufficient. This can be particularly true for nitrogen monitoring requirements. For example, the Bioclere system has general use approval from DEP to be installed in place of a standard Title 5 system. As part of this approval, the system must only be monitored for pH, BOD, and TSS. The system also has provisional use approval for nitrogen removal; when installed in areas subject to nitrogen loading limitations it must also be monitored for nitrate, ammonia, and total Kjeldahl nitrogen. The hitch comes in the definition of areas subject to nitrogen loading limitations. Many coastal communities have areas, such as zones of recharge to embayments, that they consider to be nitrogen sensitive but which do not formally meet the Title 5 definition of nitrogen sensitive areas (Zone IIs of public supply wells, areas served by both private wells and septic systems, and other areas formally designated by the state as nitrogen sensitive). The board may allow (and even encourage) the installation of nitrogen removal systems in areas that the board considers nitrogen sensitive. But, it is unclear whether the Bioclere unit, when installed in an area that is not nitrogen sensitive, will have to monitor for nitrogen. To ensure that any system is monitored to the satisfaction of the Board of Health, the board may want to make monitoring requirements a condition of its approval of the system. However, sections 15.285(2), 15.286(5), and 15.288(4) specify that this can only be done after adopting regulations, pursuant to 310 CMR 15.003(3), that allow the Board of Health to impose its own conditions and monitoring requirements on systems. A proposed regulation for your consideration is given at the end of this chapter.

CHANGE OF OWNERSHIP

Boards of Health must also consider the issue of change of ownership of properties at which alternative technologies are installed. Because these technologies require financial obligations from owners for maintenance and monitoring, it is essential that any potential buyer be aware of these obligations before they purchase the property. As part of its the Piloting, Provisional, Remedial and General Approval for most systems, DEP requires that the owner provide written notice to any potential buyer of DEP's Approval for the system (including all conditions and requirements for the system's use) prior to signing a purchase and sale agreement. Although anyone who neglects to provide this notification may be subject to civil liability, it is in the Board of Health's interest to be sure that property purchasers understand their responsibilities before they purchase property with an alternative system. For this reason, the Board of Health may wish to require that anyone who installs an alternative system **record use of such on the property's deed**, along with any restrictions placed on the use of the property (number of bedrooms, etc.) by the Board of Health. The Board of Health may also require, as one of its conditions of approval, that at the time of sale the seller provide a letter from the system operator stating that the system has been properly maintained.

MISAPPLICATION OF TECHNOLOGY

Another issue which merits consideration is the potential for misapplication of alternative technologies. Most Board of Health members are aware that the use of alternative technologies is most frequently proposed at environmentally sensitive and difficult sites: sites that require significant variances from Title 5; sites seeking increased density based on nitrogen credits, etc. One common scenario is that of a site where horizontal setbacks to a critical resource such as a well or watercourse cannot be met. The applicant may propose use of an alternative technology which removes nitrogen as a way of providing an equal degree of public health and environmental protection. However, in this instance, pathogens are the issue that should most concern the board. Unless the technology is capable of pathogen reduction, use of the system is a misapplication of the technology, does not provide equal protection, and should not be allowed. Boards of Health should scrutinize applications for alternative technology to ensure that the technology provides appropriate environmental and public health protections to address concerns on a specific site.

Systems must also be used and installed in accordance with the manufacturer's design specifications. For instance, systems are frequently designed (size or number of treatment units) based on the expected BOD load of the wastewater. If the BOD (or other wastewater parameter) at the actual installation varies significantly from what the unit is designed to handle, the unit will not produce good quality finished wastewater. This can be particularly true at restaurants and supermarkets where wastewater strength must be accurately known (usually by direct sampling) before the system can be properly designed. We have seen several instances where engineers have designed a treatment system either not following manufacturers specifications or in a configuration not specifically designed by the manufacturer with very negative results including poor quality finished wastewater and premature failure of the system. It is wise for the board to consult with the system distributor's representative or engineer to ensure that the distributor agrees that the system will be used as designed.

NITROGEN REMOVAL CREDITS AND ASSOCIATED INCREASES IN ALLOWABLE DESIGN FLOW

A final set of concerns centers on the nitrogen removal credits and resulting increases in allowable density that go with the use of some alternative systems. Title 5 limits sewage design flow in nitrogen sensitive areas to 440 gpd per acre unless a technology approved for nitrogen removal is used. Most units which have received nitrogen removal credits are allowed increases in density to either 550 or 660 gpd per acre. The situation is further complicated by the fact that DEP allows these credits to be used for expansions of existing dwellings on lots less than an acre in size. These credits and expansions are summarized in Table 1.

Most towns on Cape Cod have zoning or Board of Health regulations that restrict wastewater loading to 330 gpd/acre in Zone II's of public supply wells and/or in areas served by both private wells and septic systems. The use of 330 gpd/acre is based on the Cape Cod Commission nitrogen loading model (*Cape Cod Commission Technical Bulletin 91-001 (Final), Nitrogen Loading*) which predicts that combined wastewater loading from a typical three bedroom home will result in an average groundwater concentration of 5 mg/L.

In areas where a 330 gpd/acre rule applies, Boards of Health will have to decide whether to allow DEP's increased design flow/acre (based on 440 gpd/acre) or whether to scale down increased flow proportionately using a baseline of 330 gpd/acre. Table 2 summarizes the wastewater loading credit that would be allowed for each technology using a baseline flow of 330 gpd/acre.

Lastly, there may be land areas where the Board of Health's goal is to attain nitrogen loading of less than 5 mg/L. These areas may include recharge zones to selected coastal embayments and densely built barrier beaches. A Board of Health may also choose lower nitrogen loadings per acre in areas where groundwater nitrate already exceeds 5 mg/L. In these cases, the board may want to require the use of alternative technologies but may not be willing to grant the wastewater flow increases that DEP allows for the technology. Boards will likely confront this scenario on small lots in recharge areas of coastal embayments where homeowners wish to upgrade and expand existing dwellings. The Board of Health may wish to require nitrogen removal technology but will have to decide how much additional wastewater flow, if any, to allow with use of these technologies.

Final Note

The prospect for continued and expanded use of alternative onsite septic system technology looks good. As the septic system further evolved from the temporary solution it was once thought of, to the long term solution, communities will be tempted to apply these technologies in broad areas. We would encourage Boards of Health, faced with large areas of critical concern to begin discussions with all appropriate agencies (DEP, local Planning Boards, Water and Sewer Boards, etc) to ensure that onsite treatment is the way to go. There is a broad gradient of solutions to area problems relating to wastewater management that range from all onsite treatment to large centralized municipal treatment. In between there are "packaged" treatment facilities and technologies that have scaled up to meet the small cluster possibilities. We will discuss these technologies in future newsletters, but suffice to say, despite our and your excitement over the onsite possibilities, don't "jump the gun" before looking at the long range plan.

Proposed Regulation Regarding Board of Health Requirements for Monitoring of Alternative Septic Technologies

In considering the permitting and use of various alternative septic treatment technologies in the Town of ____________, the Board of Health of the Town of _________________ recognizes that there may be specific local circumstances which warrant the Board to require more stringent conditions for the installation and monitoring of these alternative systems than may be required by the Massachusetts Department of Environmental Protection. As allowed under Massachusetts General Laws Chapter 111, section 31 and as required by the revised 310 CMR 15.00 sections 15.285(2d), 15.286(5), and

15.2888(4), the Board of Health of the Town of _____________ hereby reserves the right to impose any additional conditions or monitoring requirements it views as necessary to ensure the safe performance of any alternative onsite septic system which the board agrees to permit in the Town of ______________.

Table 1. Summary of allowable increases in design flow (per acre or portion thereof) based on DEP baseline design flow of 440 gpd/acre in areas where nitrogen loading is limited.

Name of technology	% reduction in nitrogen	Total nitrogen mg/L	% increase in design flow	gpd per 40,000 s.f. acre	gpd per 30,000 s.f. (0.75 acre)	gpd per 20,000 s.f. (0.5 acre)	gpd per 15,000 s.f. (0.37 acre)	gpd per 10,000 s.f. (0.25 acre)
standard Title 5 system	0	40	0	440	330	220	165	110
RSF (residential; Amphidrome Bioclere Cromaglass FAST (nonresidential)	40	25	25	550	425	250	206	125
	45	23						
	50	21						
Amphdrome Bioclere Cromaglass FAST (non-residential)	55	19	50	660	455	330 for new construction; 440 for expansion of existing 3 BR home	247 for new construction; 440 for expansion of existing 2BR home	165 for new construction 330 for expansion o existing 2 B home
FAST (seeking for approval for)	64	15	75	770				
		<10		Potentially unlimited				

Table 2. Summary of allowable increases in design flow (per acre or portion thereof) based on local baseline design flow of 330 gpd/acre in areas where nitrogen loading is limited.

Name of technology	% reduction in nitrogen	Total nitrogen mg/L	% increase in design flow	gpd per 40,000 s.f. acre	gpd per 30,000 s.f. (0.75 acre)	gpd per 20,000 s.f. (0.5 acre)	gpd per 15,000 s.f. (0.37 acre)	gpd per 10,000 s.f. (0.25 acre)
standard Title 5 system under local regs	0	40	0	330	248	165	110	82.5
RSF (residential; Amphidrome Bioclere Cromaglass FAST (nonresidential)	40	25	25	412	309	206	155	103
	45	23						
	50	21						
Amphdrome Bioclere Cromaglass FAST (non-residential)	55	19	50	495	371	247 for new construction; 330 for expansion of existing 3 BR home	185 for new construction; 330 for expansion of existing 2BR home	123 for new construction 246 for expansion o existing 2 B home
FAST (seeking for approval for)	64	15	75	577				
		<10		Potentially unlimited				

DEP APPROVAL PROCESS FOR ALTERNATIVE SYSTEMS

In the 1995 revisions to Title 5, the Department of Environmental Protection for the first time allowed the use of non-Title 5, or alternative, septic systems. Any system designed or constructed in any manner other than described in Title 5 will be considered an alternative system. These alternative systems may include substitutes or alternatives for one or more parts of a conventional on-site system, or may be fundamentally different approaches intended to eliminate the need for a standard Title 5 system.

Before being used, each new type of alternative technology must be reviewed and receive approval from DEP. This is accomplished through a three-tiered approval process, which consists of **Piloting, Provisional, and General Use approval**. Through this process, manufacturers of alternative systems are allowed to install, monitor, and demonstrate the effectiveness of a limited number of systems. As data is gathered demonstrating that the system functions as effectively as projected, the system moves through the approval process and more systems are allowed to be installed. The goal of the approval process is to allow the applicant to demonstrate that the system functions at least as well as, or better than, a conventional Title 5 system to protect the public health, safety, and the environment. When this has been demonstrated, General Use approval is given to the system.

Aside from Piloting, Provisional, and General Use Approval, systems may also receive **Remedial Use Approval** for use in repair situations. In addition, technologies that are designed to remove nitrogen from the finished wastewater may also receive approval for a **Nitrogen Removal Credit.**

As part of the approval process, DEP imposes strict monitoring requirements on each system. DEP requires that all systems with Piloting or Provisional Use approval at a minimum to monitor influent and effluent for pH, TSS, and BOD. Many alternative systems claim that they produce better quality effluent than a conventional Title 5 system, or that installation of the system should be subject to less stringent requirements than those of Title 5. DEP generally requires monitoring for parameters which can be used to evaluate these claims and document the system's treatment capabilities. For example, systems that claim to reduce nitrogen are usually monitored for total Kjeldahl nitrogen, nitrate and ammonia. Systems that claim to reduce pathogens may also be required to monitor for fecal coliform and possibly viruses.

DEP also imposes fairly strict requirements on where these technologies may be installed. Technologies with piloting or provisional use approval may only be installed where 1) the proposed use is for upgrade of an existing failed or substandard system with **no increase in design flow to the system** or 2) the system will be used for new construction or increased flow at a site where a system in compliance with Title 5 exists or could be constructed; or 3) the system will be used for new construction or increased flow at a site where connection to a sewer is possible. If the alternative technology does not perform as expected, the owner of the system will have to replace it with a Title 5 system.

Each step of the three-tiered approval process is described in more detail below.

Systems first receive **Piloting Use Approval**. Piloting approval authorizes the installation of a limited number (<15) of systems to provide field testing and demonstration that the system can or cannot function effectively. The local Board of Health and DEP must approve each individual piloting facility prior to the use of the system. DEP determines the monitoring schedule and parameters for each system as part of its piloting approval. DEP will generally require systems with piloting approval to monitor monthly for the first 6 -12 months, and quarterly thereafter for up to two years. The Board of Health may impose additional requirements for monitoring and use of the system under regulations adopted pursuant to section 15.003(3) of Title 5. Permitting is fairly simple. If DEP variances are not needed, send a copy of the local application approval together with a supplemental transmittal form (you can get a copy of the form from the manufacturer or DEP) to the Boston office of DEP. If Title 5 variances are needed, the applicant must send local Board of Health approval, engineered plans, and permit application BRP WP 59b plus a $200 filing fee to the DEP Regional Office.

Upon satisfactory completion of piloting testing (the results of up to 15 systems tested for 2 years), DEP may grant provisional approval of the system, determine that additional pilot testing is required, or disapprove the system. Piloting is considered successful when at least 75% of the piloted systems have performed at the expected level of treatment for at least 12 months. DEP may waive piloting and grant Provisional use approval when the applicant can demonstrate past performance of the system for at least two years of general usage in another state.

After successful piloting, systems move on to **Provisional Use Approval**. Provisional use approval is intended to evaluate whether a technology can provide an equivalent degree of environmental protection as a Title 5 system, under actual field conditions. Under provisional use approval, a minimum of 50 systems are installed and monitored for three years for the same parameters required under piloting approval. DEP uses this data to set final discharge standards and other conditions of use for the system. The Board of Health may impose additional monitoring or use requirements on the system under regulations adopted pursuant to section 15.003(3) of Title 5. Permitting is the same as for systems with piloting approval. If no Title 5 variances are necessary, the local Board of Health approval and engineered plans for the system are forwarded to DEP Boston along with the manufacturer's transmittal form. No fee is required. If Title 5 variances are required, the Board of Health approval, engineered plans, and DEP permit BRP WP 59b (for setback variances) or BRP WP 64c (for all repairs; i.e. remedial use variances) or BRP WP 64b (for other new construction variances) and a $200 or $300 filing fee are sent to the DEP Regional office.

A system has demonstrated effective performance when at least 90% of provisionally approved systems have performed at a level at least equivalent to a that of a standard on-site system over the period of the provisional approval. When this is accomplished, the system is granted **General Use Certification.** This means that the technology is regarded by DEP as providing a level of environmental protection at least equivalent to that provided by a standard on-site system designed and constructed in accordance with Title 5. Systems that have received General Use certification do not require a permit from DEP for installation unless Title 5 variances are required. However, a Disposal Works Construction Permit from the Board of Health is required and the board, as the local approving authority, makes the decision whether the system can be installed. The system must be installed and operated in accordance with any conditions established by DEP as part of the system's general use certification. DEP may or may not require monitoring as part of a system's general use certification. The Board of Health may impose additional monitoring or use requirements on the system under regulations adopted pursuant to section 15.003(3) of Title 5. As above, if Title 5 variances are needed for the installation, plans must be sent to the DEP Regional Office with permit BRP WP 59b and a $200 filing fee.

Alternative systems may also be granted **Remedial Use Approval**. Remedial Use Approval is intended to allow installation of an alternative system for repairs at sites that often cannot accommodate a standard Title 5 system. Remedial use approval usually allows some reduction in the requirements of Title 5. Typically this includes a reduction in the size of the leaching field, a reduction in the required separation to groundwater, or a reduction in the required depth of naturally occurring pervious soil under the leaching field. These reductions are generally not much different from the reductions allowed for standard Title 5 systems under local upgrade approval for replacement of failed systems. The reductions are intended to allow owners to replace their failed septic system in a cost effective way while improving site conditions. Permitting is similar to that described above for systems with provisional use approval. If within the authority of local upgrade approval, no application to DEP is required. If DEP variances are needed, the Board of Health approval, engineered plans, and DEP permit BRP WP 59b (for setback variances) or BRP WP 64c (for all other variances) and a $200 or $300filing fees are sent to the DEP Regional office.

Many systems, as part of their approval process, apply to DEP for **Nitrogen Removal Credits**. Title 5 restricts design flow to 440 gpd per acre in designated nitrogen sensitive areas (zone II's of public supply wells, in areas served by both private wells and on-site septic systems, and in other areas formally designated as nitrogen sensitive). Some alternative technologies are specifically designed to remove nitrogen from finished effluent, and many of these systems seek a nitrogen removal credit. A nitrogen removal credit allows the property owner an increase in design flow per acre. For example, a home located on a half-acre (20,000 s.f.) in a nitrogen sensitive area would be restricted under Title 5 to a two bedroom, or 220 gpd, design flow. The owner may choose to install an alternative system that has a nitrogen removal credit allowing a 660 gpd/acre design flow. This will allow the homeowner to construct a three bedroom, or 330 gpd design flow, house on the lot. Manufacturers of nitrogen-removal technologies hope that the increase in design flow allowed by the nitrogen removal credit will make nitrogen-removal technologies economically attractive. A number of systems have received either General or Provisional approval for a nitrogen removal credit, usually either 550 or 660 gpd per acre.

Typically, an alternative system may be granted several types of approval at one time. For example, DEP may grant a system General Use Certification for use on a lot that can accommodate a Title 5 system, with no expectation that the system will perform better than a Title 5 system. The alternative system may simultaneously have Remedial Use approval for a reduction in required leachfield size for repair installations on lots that require Title 5 variances. The system may also have Provisional Use approval for a nitrogen removal credit, so that it could be installed (possibly with associated increases in design flow) where nitrogen reduction is desired.

Each type of use approval may have different monitoring requirements associated with it, so it is up to the Board of Health to make sure that the system is being monitored to their satisfaction, and to require additional monitoring if the board feels this is necessary. For example, a system may have general use approval with no monitoring requirements and have a nitrogen reduction credit. The system may be installed in an area that has not been designated as nitrogen sensitive; this happens most frequently in coastal areas that Boards of Health may consider nitrogen sensitive but which have not been formally so designated. In these cases, even though the system is being used for nitrogen reduction, DEP will not require the system to be monitored for nitrogen output and the Board of Health will want to impose this requirement itself.

To date, 20 systems have entered the DEP approval process and are summarized in Table 1. More detailed information about each system, including permitting and use conditions are given in Table 2.

1997, and Type of Approval Received to Date.

Certified for General Use

Composting toilets
AWT Bioclere
RUCK
Saneco (Orenco) Intermittent sand filter
Recirculating sand filters
Cromaglass
S&L Single Home and Modular FAST

Cultec
Envirochamber
PSA Biodiffusor
Eljen In-Drain
Infiltrator

Approved for Provisional Use

AWT Bioclere
Biolet XL
S&L Single Home and Modular FAST

Approved for Piloting

Amphidrome Process
KROFTA Compact Clarifier
Waterloo Biofilter
Cromaglass
Solviva Biocarbon filter

Approved for Remedial Use

Recirculating sand filter
AWT Bioclere
JET Aerobic
Saneco ISF
S&L Single Home and Modular FAST
Composting toilets
Biolet XL
Jet Sand filter
Waterloo Biofilter

Applications Currently under DEP Review

Biodiffusor (Provisional)
Clivus composter (Remedial)
Clivus Greywater system (Provisional)
Cycle-Let (Provisional)
Envirochamber (Provisional)
Gloucester RSF (Remedial)
Hydrogen Peroxide (Remedial)
Infiltrator (Provisional)
Orenco ISF (Provisional)
Orenco Shallow Trench (General)
Norweco Singulair (General)

Introduction

Until relatively recently, technology for the onsite treatment of household sanitary waste in Massachusetts was relatively "standard" , involving in most cases a septic tank for the settling of solids and mineralization1 of wastes, and a leachfield for the safe disposal of the liquefied waste in appropriate locations away from points of possible human exposure. A frank assessment of this technology is that its primary focus is on disposal, following some rudimentary treatment. Ultimate "treatment" in standard systems is primarily due to dilution, dispersion and retention in underlying soils until pathogens are rendered harmless. The lack of focus on actual treatment of waste onsite is primarily attributable to the thought that the onsite septic system was a temporary means of waste disposal until such time as the community constructed centralized sewage treatment facilities. With the withdrawal of federal support for centralized wastewater collection and treatment facilities and the economic realities associated with such, communities now recognize that the onsite septic system is evolving into the long-term wastewater solution for many areas. The problem generally recognized under the paradigm of onsite septic system use is that research continues to verify that certain resource areas, such as drinking water aquifers and watersheds of marine and freshwater resources, can no longer tolerate the mere disposal of wastes. Many communities are now inquiring as to what options are available to actually treat wastewater for harmful constituents near their source of generation - onsite. Until recently, however, options for the widespread use of "alternative" onsite septic systems were fairly limited.

In March, 1995, the landscape of alternative septic system use in Massachusetts was dramatically changed. Up to this point, alternative methods for disposing of sanitary waste onsite were generally rare; most installations involved composting toilet technology that was allowed at the time. The March, 1995 changes to the onsite septic system regulations in Massachusetts (CMR 15.00, commonly referred to as Title 5) however, describes the various approval processes for more widespread use of alternative onsite septic system technologies. These past two years have witnessed both a clarification of the permitting process and a proliferation of the technologies statewide.

The quest for the better "mousetrap" in onsite septic system technology in Massachusetts began in the early 1990's. In February, 1992, the Waquoit Bay National Estuary Research Reserve (WBNERR) sponsored the first conference on alternative onsite septic system (AOSS) technology to be held in Barnstable County. As participants heard of the various states' programs for alternative septic system use, many wondered what was preventing their use in Massachusetts. These questions were somewhat answered, however, as the stories from various states revealed the two-edged-sword nature of alternative septic systems. On the one side, AOSS can address both limiting physical conditions (soil percolation rate or distance to groundwater, space, etc.) and pollution problems (nitrogen in particular). On the other side AOSS technology could, without adequate planning controls, open up new areas to development that were otherwise restricted in part by then-present Title 5 constraints.

Nevertheless, 1993-1997 has witnessed a number of research and demonstration projects to demonstrate the efficacy of AOSS technologies. A particular aspect of AOSS introduction to Massachusetts at this point bears mention. In many other parts of the country, AOSS were introduced primarily to address the issue of poorly-percolating or otherwise limiting soil conditions as opposed to addressing the various nonpoint pollution issues of onsite septic system use. Many USEPA studies focusing on marine and estuarine water quality (including two in Massachusetts - the Buzzards Bay Project and the Massachusetts Bays Project), however, confirm the need to address the issues of nitrogen and pathogen contribution to marine systems from onsite septic systems. Accordingly, the focus of most of the demonstration projects in Massachusetts has been to demonstrate the reduction of both pathogens and nitrogen.

The first demonstration project in Massachusetts for AOSS continues until today in the City of Gloucester. Faced with the pressure to expand their sewage treatment facility, city officials there sought to demonstrate that onsite solutions were feasible both from the treatment aspects, as well as economically. Since then, demonstration projects have proceeded under support from the Massachusetts Department of Environmental Protection (under the 319(b) Program - four systems are being installed between the towns of Provincetown, Eastham, Wellfleet, and Truro), the Massachusetts Bays Program (five systems have been installed in Wellfleet under the MiniBays subprogram), the Buzzards Bay Program (two systems have been installed in that watershed, with one more soon to be installed), and WBNERR (four different technologies have been installed and are being monitored under the National Onsite Demonstration Program of EPA). In addition, a cooperative project between the Barnstable County Department of Health and the Environment, Dr. Brian Howes of the Center for Marine Science and Technology (CMAST) of the University of Massachusetts at Dartmouth, and the Buzzards Bay Project, endeavors to construct an AOSS technology testing facility under a program called Environmental Technology Initiative (ETI). The testing facility is to be constructed at the Massachusetts Military Reservation.

If you have been a regular reader of the newsletter from which this document is derived, you will notice that the following chapters do not, for the purpose of logical presentation of the information, contain the following two "warnings", which were sporadically echoed in the newsletter. The first warning relates to the fact that, although often not officially stated, Title 5 has in the past been used as a de facto density control. As AOSS develops, municipalities should heed the "heads up" that should have already been heard. If proper planning instruments are not in place to articulate what a community wants to be (i.e. what densities of residential housing it desires or can support), it is quite possible that the advancing technologies will allow higher density of development than communities might desire. Already, relating to the issue of nitrogen loading, proponents wishing to develop at higher density can obtain "credits" for doing so by using AOSS (see chapter on permitting). The second "warning" is more specific to Boards of Health and other individuals who are applying AOSS technology. The caution here is merely to understand the technology before applying it to a specific problem. The most common misapplication of AOSS we have seen is the situation where a Board of Health allows the installation of AOSS to compensate for the inability of a proponent to meet a setback requirement of 100 feet from a watercourse. In these instances we have seen denitrifying technologies allowed to compensate for a setback that was predicated on pathogen (specifically virus) concerns. In short, unless the technology being proposed addresses the issue that is central to your setback requirement, it should not be considered a compensating action by the proponent.

In closing to this introduction, the authors would again like to remind the reader that this compendium is not the "final word" on AOSS. Through various funding supports, the Barnstable County Department of Health and the Environment intends to continue to produce the newsletter from which this document was derived. In the next year, support is provided in part by the Massachusetts Bays Project, and the Department of Environmental Protection through a 319(b) grant to our Department. The authors again wish to express thanks to all those individuals, notably the staff of DEP Division of Wastewater Management who continue to contribute to the accuracy of the documents.

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BASICS OF WASTEWATER TREATMENT

Before you go on to read about the individual technologies discussed later in this document, it is helpful to understand some of the basics of wastewater treatment. You will see terms like BOD, total suspended solids, nitrification, and denitrification frequently when discussing wastewater treatment. It is important to understand what each of these terms mean and how each relates to the wastewater treatment process. Some very basic processes of wastewater treatment are also briefly discussed. If you understand the theory behind these basic treatment processes it is easy to see how and why the processes are applied in the various alternative technologies discussed later.

BASIC CONSTITUENTS OF WASTEWATER

Biochemical oxygen demand

One of the most commonly measured constituents of wastewater is the **biochemical oxygen demand, or BOD**. Wastewater is composed of a variety of inorganic and organic substances. Organic substances refer to molecules that are based on carbon and include fecal matter as well as detergents, soaps, fats, greases and food particles (especially where garbage grinders are used). These large organic molecules are easily decomposed by bacteria in the septic system. However, oxygen is required for this process of breaking large molecules into smaller molecules and eventually into carbon dioxide and water. The amount of oxygen required for this process is known as the biochemical oxygen demand or BOD. The Five-day BOD, or BOD_5, is measured by the quantity of oxygen consumed by microorganisms during a five-day period, and is the most common measure of the amount of biodegradable organic material in, or strength of, sewage.

BOD has traditionally been used to measure of the strength of effluent released from conventional sewage treatment plants to surface waters or streams. This is because sewage high in BOD can deplete oxygen in receiving waters, causing fish kills and ecosystem changes. Based on criteria for surface water discharge, the secondary treatment standard for BOD has been set at 30 mg BOD/L (i.e. 30 mg of O_2 are consumed per liter of water over 5 days to break down the waste).

However, BOD content of sewage is also important for septic systems. Sewage treatment in the septic tank is an anaerobic (without oxygen) process; in fact, it is anaerobic because sewage entering the tank is so high in BOD that any oxygen present in the sewage is rapidly consumed. Some BOD is removed in the septic tank by anaerobic digestion and by solids which settle to the bottom of the septic tank, but much of the BOD present in sewage (especially detergents and oils) flows to the leaching field. Because BOD serves as a food source for microbes, BOD supports the growth of the microbial biomat which forms under the leaching field. This is both good and bad. On the one hand, a healthy biomat is desired because it is capable of removing many of the bacteria and viruses in the sewage so that they do not pass to the groundwater. The bacteria in a healthy biomat also digest most of the remaining BOD in the sewage. Too much BOD, however, can cause excessive growth of bacteria in the biomat. If the BOD is so high that all available oxygen is consumed (or if the leaching field is poorly aerated, as can be the case in an unvented leaching field located under pavement or deeply buried) the biomat can go anaerobic. This causes the desirable bacteria and protozoans in the biomat to die, resulting in diminished treatment of the sewage. Low oxygen in the biomat also encourages the growth of anaerobic bacteria (bacteria which do not require oxygen for growth). Many anaerobic bacteria produce a mucilaginous coating which can quickly clog the leaching field. Thus, excess BOD in sewage can cause a leaching field to function poorly and even to fail prematurely.

Many of the enhanced treatment technologies discussed later in this document were designed specifically to reduce BOD in treated sewage. BOD removal can be especially important where sewage effluent flows to a leaching field in tight soils. Tight soils are usually composed of silts and clays (particle size < 0.05 millimeter). These small soil particles are tightly packed and the pore space between them is small. Reducing BOD means that the sewage will support the growth of less bacteria and therefore the effluent will be better able to infiltrate tight soils. Many enhanced treatment technologies that remove BOD were designed specifically to enhance disposal of effluent in tight silt or clay soils.

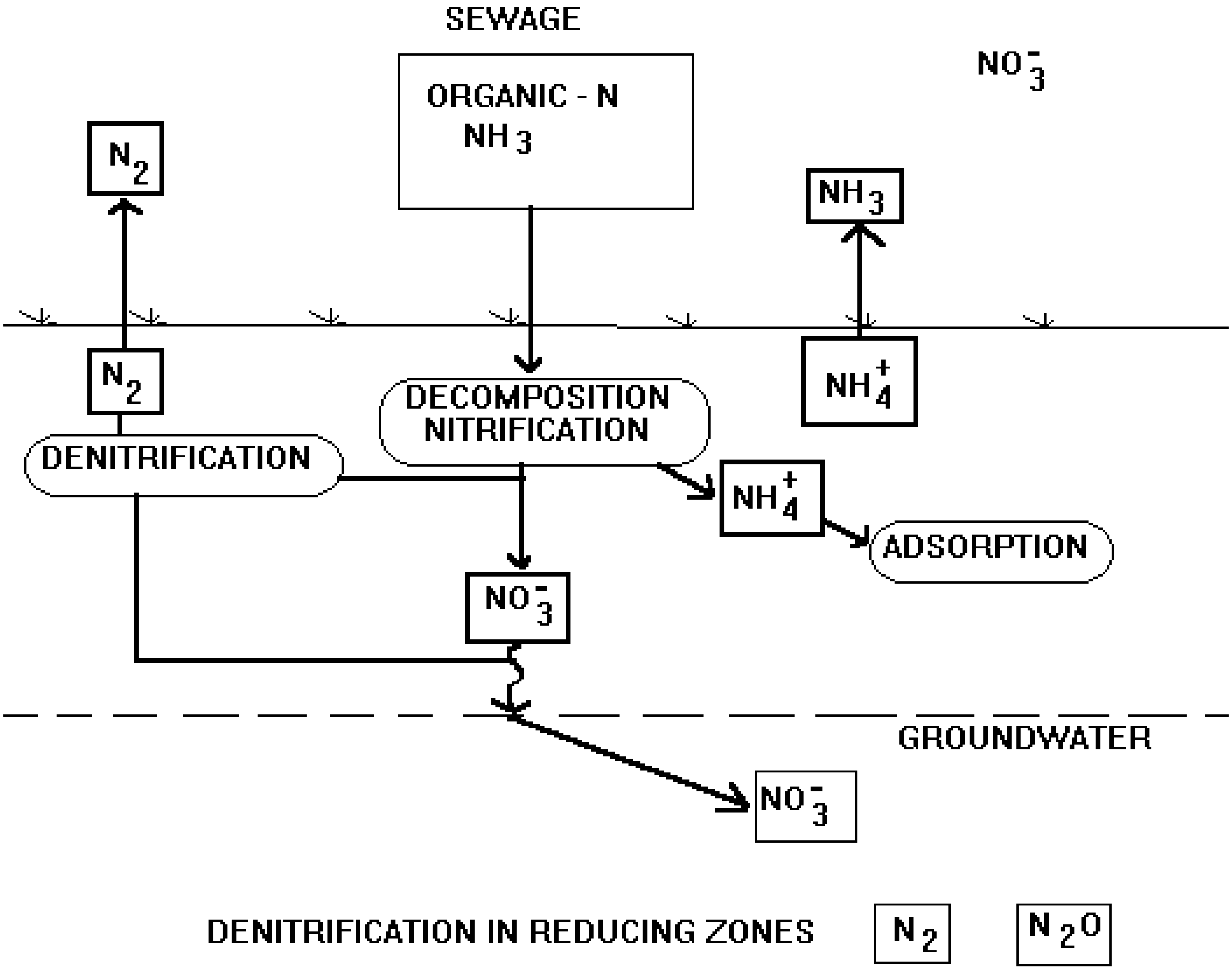
BOD is fairly easy to remove from sewage by providing a supply of oxygen during the treatment process; the oxygen supports bacterial growth which breaks down the organic BOD. Most enhanced treatment units described incorporate some type of unit which actively oxygenates the sewage to reduce BOD. This unit is often located between the septic tank and the leach field. Or, it can be located within the septic tank in a specific area where oxygen is supplied. Reduction of BOD is a relatively easy and efficient process, and results in sewage of low BOD flowing to the leaching field. It is important to note, however, that low BOD in sewage may result in a less effective biomat forming under the leaching field.

It is also important to note that BOD serves as the food source for the denitrifying bacteria which are needed in systems where bacterially-mediated nitrogen removal takes place. In these situations BOD is desired, as the nitrification/denitrification process cannot operate efficiently without sufficient BOD to support the growth of the bacteria which accomplish the process.

Total suspended solids

Domestic wastewater usually contains large quantities of suspended solids that are organic and inorganic in nature. These solids are measured as **Total Suspended Solids or TSS** and are expressed as mg TSS/ liter of water. This suspended material is objectionable primarily because it can be carried with the wastewater to the leachfield. Because most suspended solids are small particles, they have the ability to clog the small pore spaces between soil grains in the leaching facility. There are several ways to reduce TSS in wastewater. The simplest is the use of a septic tank effluent filter, such as the Zabel filter (several other brands are available). This type of filter fits on the outlet tee of the septic tank. It is made of PVC with various size slots fitted inside one another. The filter prevents passage of floating matter out of the septic tank and, as effluent filters through the slots, fine particles are also caught. Many types of alternative systems are also able to reduce TSS, usually by the use of settling compartments and/or filters using sand or other media.

Total nitrogen



Nitrogen is present in many forms in the septic system. Most nitrogen excreted by humans is in the form of organic nitrogen (dead cell material, proteins, amino acids) and urea. After entering the septic tank, this organic nitrogen is broken down fairly rapidly and completely to ammonia, NH_3, by microorganisms in the septic tank. Ammonia is the primary form of nitrogen leaving the septic tank. In the presence of oxygen, bacteria will break ammonia down to nitrate, NO_3. In a conventional septic system with a well aerated leaching facility, it is likely that most ammonia is broken down to nitrate beneath the leaching field.

Nitrate can have serious health effects when it enters drinking water wells and is consumed. Nitrate and other forms of nitrogen can also have deleterious effects on the environment, especially in coastal areas where excess nitrogen stimulates the process known as eutrophication. For this reason, many alternative technologies have been designed to remove total nitrogen from wastewater. These technologies use bacteria to convert ammonia and nitrate to gaseous nitrogen, N_2. In this form nitrogen is inert and is released to the air.

Biological conversion of ammonia to nitrogen gas is a two step process. Ammonia must first be oxidized to nitrate; nitrate is then reduced to nitrogen gas. These reactions require different environments and are often carried out in separate areas in the wastewater treatment system.

The first step in the process, conversion of ammonia to nitrite and then to nitrate, is called nitrification ($NH_3 \longrightarrow NO_2\ NO_3$). The process is summarized in the following equations:

$$NH_4 + 3/2\ O_2 \longrightarrow NO_2^- + 2H^+ + H_2O$$

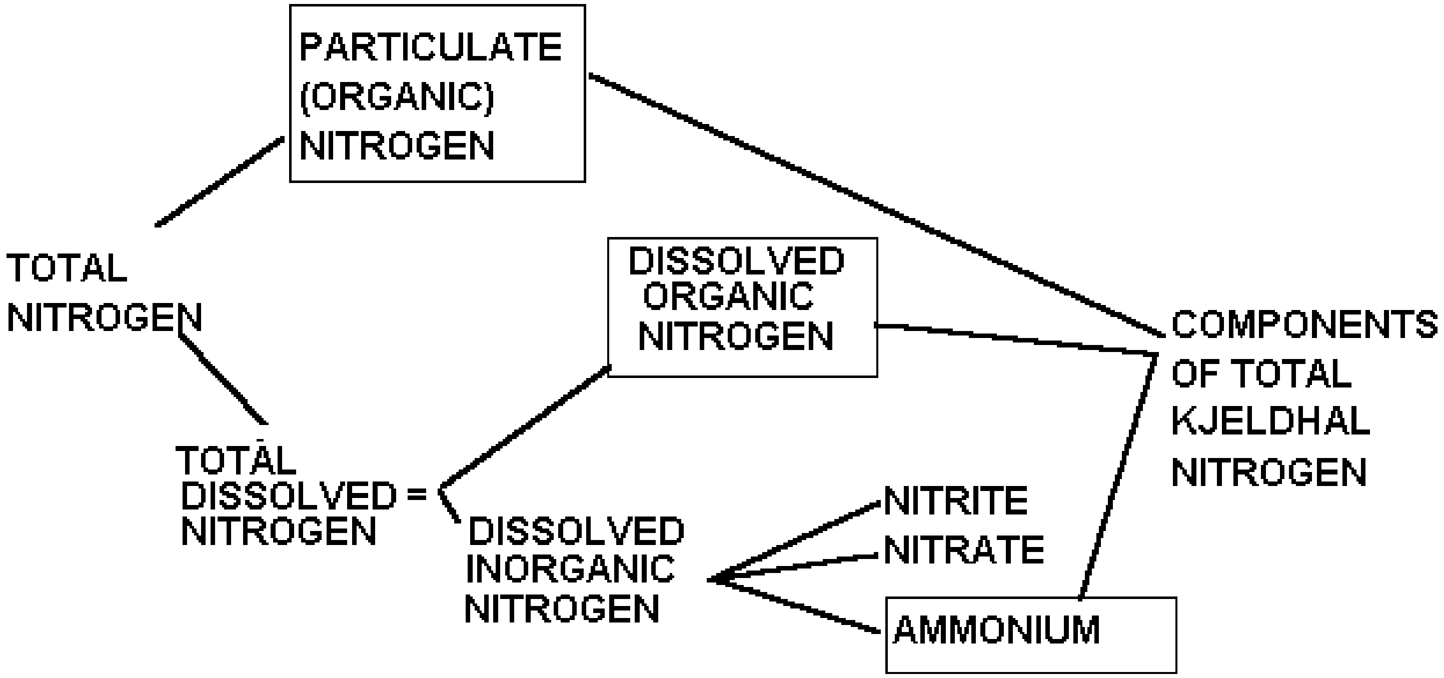
$$NO_2^- + 1/2\ O \rightarrow NO_3^-$$

It is important to note that this process requires and consumes oxygen. This contributes to the BOD or biochemical oxygen demand of the sewage. The process is mediated by the bacteria *Nitrosomonas* and *Nitrobacter* which require an aerobic (presence of oxygen) environment for growth and metabolism of nitrogen. Thus, **the nitrification process must proceed under aerobic conditions.**

The second step of the process, the conversion of nitrate to nitrogen gas, is referred to as **denitrification**. This process can be summarized as:

$$NO_3^- + 5/6\ CH_3OH \rightarrow 1/2\ N_2 + 5/6\ CO_2 + 7/6\ H_2O + OH^-$$

This process is also mediated by bacteria. For the reduction of nitrate to nitrogen gas to occur, the dissolved oxygen level must be at or near zero; the denitrification process must proceed under anaerobic conditions. The bacteria also require a carbon food source for energy and conversion of nitrogen. The bacteria metabolize the carbonaceous material or BOD in the wastewater as this food source, metabolizing it to carbon dioxide. This in turn reduces the BOD of the sewage, which is desirable. However, if the sewage is already low in BOD, the carbon food source will be insufficient for bacterial growth and denitrification will not proceed efficiently.



Clearly, any wastewater treatment unit that is going to remove nitrogen by the nitrification/denitrification process must be designed to provide both aerobic and anaerobic areas so that both nitrification and denitrification can proceed. As you look at the nitrogen removal technologies discussed later in this document, you will see how various designs have attempted to solve this problem in some unique and interesting ways.

Phosphorus

Phosphorus is a constituent of human wastewater, averaging around 10 mg/liter in most cases. The principal forms are organically bound phosphorus, polyphosphates, and orthophosphates. Organically bound phosphorus originates from body and food waste and, upon biological decomposition of these solids, is converted to orthophosphates. Polyphosphates are used in synthetic detergents, and used to contribute as much as one-half of the total phosphates in wastewater. Massachusetts has banned the sale of phosphate-containing clothes washing detergent, so phosphorus levels in household wastewater have been reduced significantly from previous levels. Most household phosphate inputs now come from human waste and automatic dishwasher detergent. Polyphosphates can be hydrolyzed to orthophosphates. Thus, the principal form of phosphorus in wastewater is assumed to be orthophosphates, although the other forms may exist. Orthophosphates consist of the negative ions PO_4^{3-}, HPO_4^{2-}, and $H_2PO_4^{-}$. These may form chemical combinations with cations (positively charged ions).

It is unknown how much phosphorus is removed in a conventional septic system. Some phosphorus may be taken up by the microorganisms in the septic system and converted to biomass (of course, when these microorganisms die the phosphorus is re-released, so there really is no net loss of phosphorus by this mechanism). Any phosphorus which is removed in the septic system probably is removed under the leaching facility by chemical precipitation.

At slightly acidic pH (as is found in the soils of Cape Cod and most of New England), orthophosphates combine with tri-valent iron or aluminum cations to form the insoluble precipitates $FePO_4$ and $AlPO_4$.

$$Fe^{3+} + (H_nPO_4)^{(3-n)} \rightarrow FePO_4 + nH^+$$

$$Al^{3+} + (H_nPO_4)^{(3-n)} \rightarrow AlPO_4 + nH^+$$

Domestic wastewater usually contains only trace amounts of iron and aluminum. However, the sandy soil of Cape Cod frequently contains significant amounts of iron bound to the surface of sand particles. It is likely that this iron binds with phosphorus and causes some removal of total phosphorus below the leaching facility.

One caveat must need be added here. If the soil below the leaching facility becomes anaerobic, iron may become chemically reduced (changed to the Fe^{2+} form), which is soluble and able to travel in groundwater. In this case, the iron phosphate compounds may breakdown and phosphorus may also become soluble. Anaerobic conditions under the leaching facility can occur when the leaching facility is not well aerated, when there is a small vertical separation to groundwater, or when BOD in the sewage is so high that all oxygen present is depleted to oxidize BOD. In the conditions found on Cape Cod, the best method for maximizing phosphorus removal is probably to locate the leaching facility well above groundwater (>5 feet vertical separation) thereby providing a well-aerated area under the leaching field. To date, no alternative on-site technologies are capable of significant phosphorus removal. However, many are trying to achieve this goal and it is likely that within the next few years we may begin to see some technologies that are successful at phosphorus removal.

BASICS OF SEWAGE TREATMENT

The treatment of sewage is largely a biochemical operation, where chemical transformations of the sewage are carried out by living microorganisms. Different environments favor the growth of different populations of microorganisms and this in turn affects the efficiency, end products, and completeness of treatment of the sewage. Sewage treatment systems, whether they are standard septic systems or more advanced treatment technologies, attempt to create specific biochemical environments to control the sewage treatment process.

Three basic types of biochemical transformations occur as sewage is treated. The first is the removal of soluble organic matter. This is composed of dissolved carbon compounds such as detergents, greases, and body wastes, which make up much of the BOD content of the sewage. The second is the digestion and stabilization of insoluble organic matter. These are the sewage solids, such as body wastes and food particles, which make up the remainder of the BOD. The third is the transformation of soluble inorganic matter such as nitrogen and phosphorus.

The two major biochemical environments in which sewage treatment is carried out are termed **aerobic** and **anaerobic** environments. An aerobic environment is one in which dissolved oxygen is available in sufficient quantity that the growth and respiration of microorganisms is not limited by lack of oxygen. An anaerobic environment is one in which dissolved oxygen is either not present or its concentration is low enough to limit aerobic metabolism. The biochemical environment has a profound effect upon the ecology of the microbial population which treats the sewage. Aerobic conditions tend to support entire food chains from bacteria up to rotifers and protozoans. These microbes beak down organic matter using many metabolic pathways based on aerobic respiration with carbon dioxide as the main end product. Anaerobic conditions favor the growth of primarily bacterial populations and produce a different variety of end products, discussed below.

Anaerobic Digestion of Sewage

Solids in sewage contain large amounts of readily available organic material that would produce a rapid growth of microorganisms if treated aerobically. Anaerobic decomposition is able to degrade this organic material while producing much less (approximately one-tenth) biomass than an aerobic treatment process. The principal function of anaerobic digestion is to stabilize insoluble organic matter and to convert as much of these solids as possible to end products such as liquids and gases (including methane) while producing as little residual biomass as possible. It is for this reason that sewage treatment in a conventional septic tank is designed to be an anaerobic process. Organic matter treated anaerobically is not broken down to carbon dioxide; final end products are low molecular weight acids and alcohols. These may be further converted anaerobically to methane or, if sent to an environment (such as the leaching field) where aerobic bacteria are present, further broken down to carbon dioxide. Anaerobic digestion of organic matter is also a much slower process than aerobic digestion of organics and where rapid digestion of organic matter is needed an aerobic treatment process must be used.

As discussed above, an anaerobic environment is also necessary for denitrification, as the bacteria which carry out this process require anaerobic conditions to reduce nitrate to nitrogen gas. Many nitrogen-removal technologies are designed to provide an anaerobic treatment chamber as part of the treatment process.

Aerobic Treatment of Sewage

As the name implies, this process utilizes aerobic bacteria to break down sewage. The principal advantage of aerobic sewage treatment is its ability to rapidly and completely digest sewage, reducing BOD to low levels. Most of the alternative treatment technologies discussed in this document utilize some form of aerobic treatment of sewage. This process is used primarily to reduce BOD and, in systems that remove nitrogen, to nitrify the waste so that it can later be denitrified. Because the BOD in raw sewage is usually high, and available oxygen is rapidly consumed by the sewage, most aerobic treatment units are designed to supply supplemental oxygen to the sewage to keep the treatment process aerobic. Some units, such as the JET Aerobic system, use **extended aeration** to more completely digest the sewage solids. Most aerobic treatment units provide some type of artificial medium as a surface on which the sewage- digesting bacteria can grow. A variety of basic designs can be used for this purpose.

Attached culture systems are designed so that wastewater flows over microbial films attached to surfaces in the treatment unit. The surface area for growth of the biofilm is increased by placing some type of artificial media, such as foam cubes or various convoluted plastic shapes with high surface area, in the treatment chamber. This artificial media may sit in the treatment chamber with the effluent circulating through it, usually with supplemental air supplied so that treatment remains aerobic. This is the principal used by the **JET Aerobic** and **FAST** systems. Or, the media may be located outside the treatment chamber and wastewater is passed over the biofilm in intermittent doses. These designs are known as **trickle filters** and are one of the most common types of on-site treatment unit using attached cultures. Some technologies which employ trickle filters, and which are discussed in more detail later, include the **Bioclere, Orenco trickle filter**, and the **Waterloo biofilter**. Intermittent and recirculating sand filters, while located in separate chambers, can also be considered a form of trickle filter where sand is used as the media for bacterial growth. Because attached culture systems are generally aerobic, a complex community of microorganisms, including aerobic bacteria, fungi, protozoa, and rotifers, develops. These systems are capable of efficient removal of BOD. Being aerobic they will support the growth of nitrifying bacteria and can be used to nitrify wastewater, the first step in nitrogen removal.

Other aerobic systems utilize **suspended culture** of microorganisms to aerobically treat the sewage. This type of treatment assumes that a resident population of bacteria are present in the solids and sludge in the treatment unit; vigorous mixing of the sewage in the treatment compartment causes these bacteria to stay in suspension where they can aerobically digest the sewage. This principle is used by the **Cromaglass** and **Amphidrome** units as part of part of the batch reactor treatment process. It is also used in many large municipal sewage treatment plants.

The **activated sludge** process is similar to suspended culture in that it also utilizes the resident population of bacteria in the solids and sludge in the treatment unit, again, usually by mixing of the sewage so that the bacteria are kept in suspension. In the activated sludge process, however, there are usually periods where mixing ceases, and the solids are allowed to settle. It is then assumed that the sludge will become anaerobic and the anaerobic bacteria in the sludge will denitrify the waste. This is the principle used by **batch reactors**. As the name implies, batch reactors treat sewage in batches. A batch of sewage is allowed to settle so that solids are removed; the batch of sewage is then aerated and mixed and then allowed to settle for a period of anaerobic treatment (this process may be repeated several times on the same batch). When treatment is complete, the finished batch of sewage is pumped out and the next batch enters the unit to begin treatment. The **Cromaglass** and **Amphidrome** systems are examples of batch reactors.

References

Grady, C.P. Leslie and Henry C. Lim, 1980. *Biological Wastewater Treatment*. Marcel Decker, Inc., N.Y

Peavey, Howard S., Donald R. Rowe, and George Tchobanoglous, 1985. *Environmental Engineering*, McGraw Hill Inc., N.Y.

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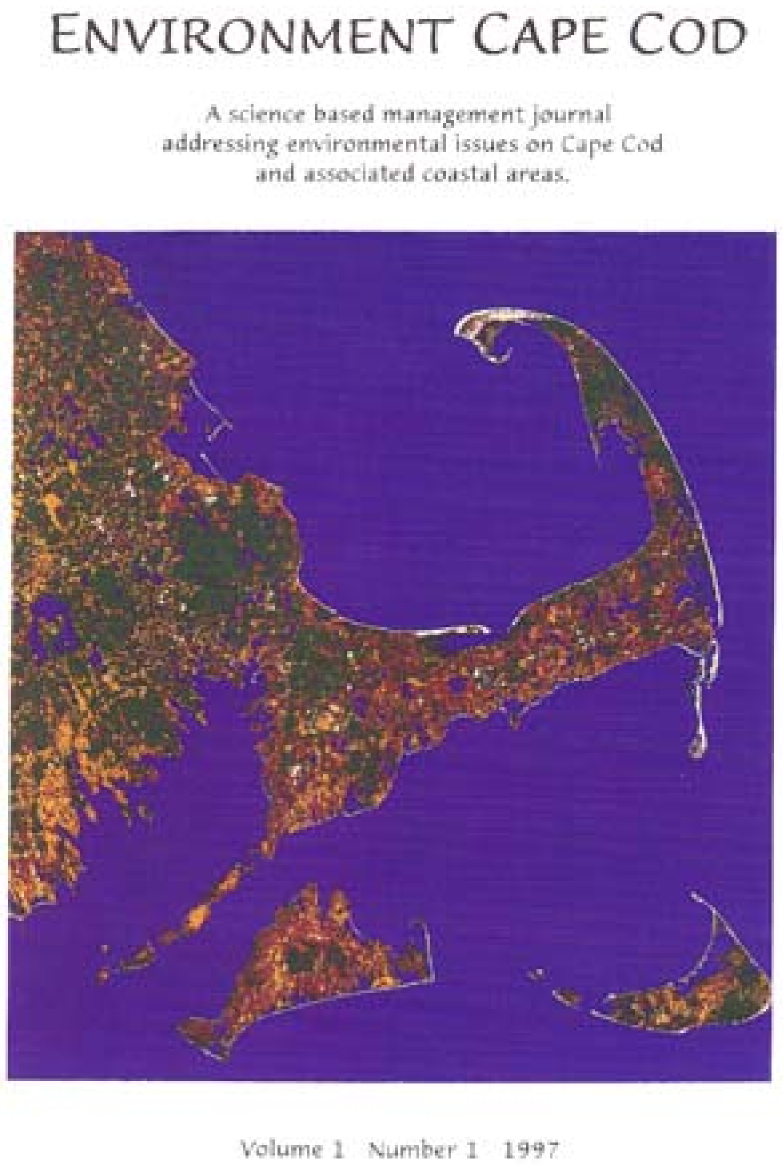

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