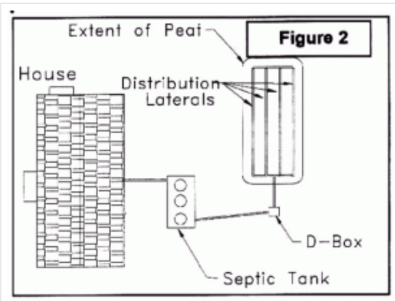
Peat Filter Septic Systems

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.

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 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.



(http://www.barnstablecountyhealth.org/library/2011/01/Peat-figure2.gif)

Figure 2. Typical layout of a simple peat system

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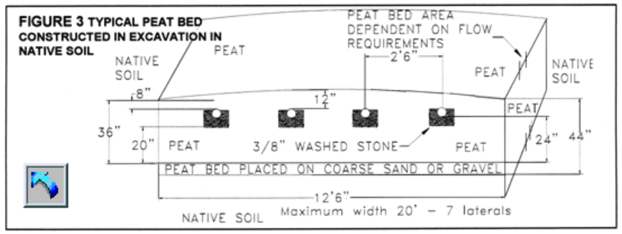

(http://www.barnstablecountyhealth.org/library/2011/01/Figure3.gif)

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

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**, marketed by American Concrete Industries in Maine and the **Puraflo^{TM} Peat Biofilter**(Figure 5 and 6), developed and marketed by Bord na Mona, the Irish Peat corporation. Design details of these systems are discussed below.

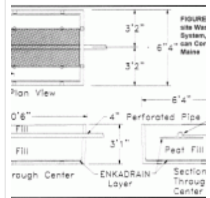

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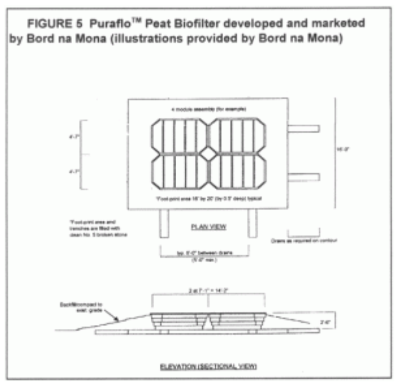
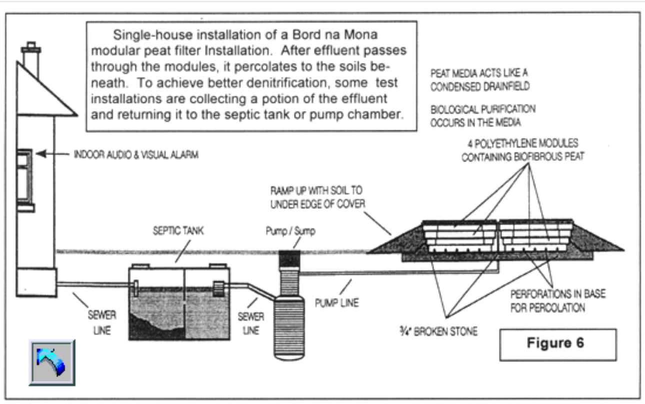
Figure 4. Enviro-pure



(http://www.barnstablecountyhealth.org/library/2011/01/Peat-figure5.gif)

Figure 5. PurafloTM Peat Biofilter developed and marketed by Bord na Mona (illustrations provided by Bord na Mona)



(http://www.barnstablecountyhealth.org/library/2011/01/Figure61.gif)

Figure 6. 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.

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 inters
space in a material to the entire volume of
material.
Peat has a porosity of about 95%, and
consequently, a very high  surface area. Pe
surface area is about 200 m2 per gram of pe
```

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
cations -- positively charged particles --
a soil can adsorb.
Peat is contains lignin-like substances whi
negatively charged. This gives peat a great
ability to adsorb positively charged molecu
Peat's high cation exchange capacity means
peat can effectively hold positively charge
molecules including ammonium, metals, pesti
some organic molecules, and possibly viruse
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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 (NO_3^-), 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 NO_3^- to N_2 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

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/100 mL peat	% removal	TSS mg/L septic tank	TSS mg/L peat
Brooks Congregate residence Maine	6	63	22	**65%**	160	<1	**99%**	10,000 -100,000	<1	**>99%**		
Brooks Congregate residence Maine	2	39	25	**36%**	138	27	**80%**	10,000 -100,000	<1	>99%		
Brooks residence Wellfleet	10	126	84	**44%**	623	45	**93%**	13,690,000	1242	**>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	2162	**98%**		
Puraflo recirc resid.MD	4	54*	24.8	**63%**	68*	2.2	**97%**	79,000*	4	**>99%**		

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

(http://www.barnstablecountyhealth.org/library/2011/01/Table1.gif)

Table 1. A summary of water quality results from a number of residential peat systems.

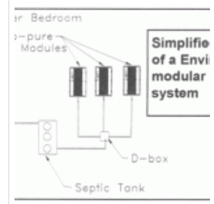
These systems include gravity fed peat beds designed by Brooks, and Puraflo modular 1-pass and recirculating systems.

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

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 **wastewater loading of 1 gal/s.f./day**.



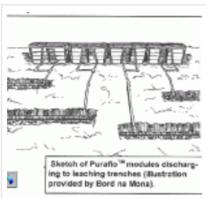
(http://www.barnstablecountyhealth.org/library/2011/01/FIGURE7.gif)

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.



(http://www.barnstablecountyhealth.org/library/2011/01/FIGURE8.gif)

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

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 which 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.

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.

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BCREPC (http://www.bcrepc.org)

Cape Cod MRC (https://www.ccmedicalreservecorps.org)

Community Septic Management Loan Program (http://www.barnstablecountyhealth.org/department-programs/community-septic-management-loan-program)

I/A Tracking Database (https://septic.barnstablecounty.org)

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