Performance of Pre-engineered Modular Peat Filters for the Treatment of Domestic Wastewater at the Northeast Regional Correction Center

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Stephen Monson Geerts
Barbara McCarthy
Richard Axler
Jerald Henneck

Natural Resources Research Institute
University of Minnesota - Duluth
5013 Miller Trunk Highway
Duluth, MN 55811

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Thank you all!

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Executive Summary

Approximately 500,000 Minnesota residences rely on the use of onsite wastewater treatment systems and >50% of these systems may be in noncompliance with state rules or are failing to the surface. A research site at the Northeast Regional Correction Center near Duluth was established in 1995, involving ~ 50 private and public sector partners, to design, construct, and monitor the performance of advanced onsite treatment systems. The systems were generally designed to treat 250 gal/day of septic tank effluent from single family homes to meet secondary treatment standards; 25 mg/L total suspended solids (TSS), 30 mg/L biochemical oxygen demand (BOD_5), and 200 cfu/100mL fecal coliform bacteria. In 1998, pre-engineered peat filters (Puraflo®, Bord Na Móna, Inc.) were installed to compare the performance of a standard Irish peat to a Bord Na Móna specified Minnesota peat. Initially, the peat filters were operated in the recirculating mode for enhanced nitrogen removal, but were changed to single-pass mode after ponding occurred. Hydraulic failure likely resulted due to cold temperatures (since the modules were not insulated) coupled with high strength waste. With minor design modifications, including foam-insulated covers, the single-pass peat filters have operated without problems. In the recirculating mode, seasonal removal rates for both types of peat ranged 86-97% TSS, 94-97% BOD_5, 96-99% fecal coliform bacteria, 6-20% total phosphorus (TP), and 31-45% total nitrogen (TN). As single-pass filters, removal rates were comparable at 89-96% TSS, 95-98% BOD_5, >99% fecal coliform bacteria, 94-99% coliphages, 0-20% TP, and 24-37% TN for both peat types. The module Puraflo® peat filter systems, using both the standard Irish peat and a Minnesota peat, performed comparably and generally exceeded secondary treatment standards.

I. Introduction

An estimated half million households in Minnesota are not connected to public sewer systems. Along with the growing use and expansion of lakeshore homes, cabins and resorts, many have the potential to degrade surface and groundwater resources, as they depend primarily on individual sewage treatment systems (ISTSs) for treatment and dispersal of domestic wastewater. Unfortunately, many are in noncompliance with state standards or are hydraulically failing to the surface. Effective treatment options are needed for the thousands of locations with restrictive soil and site conditions. Many of these conditions occur along lakes and streams, creating a potential health hazard to swimmers and others using surface water for drinking water and recreation, leading to increased algal blooms, aesthetic nuisances and degraded fish habitat.

Pre-engineered peat filters were one of several options evaluated in Minnesota since the establishment of a research facility at the Northeast Regional Correction Center (NERCC) near Duluth, Minnesota. The other systems tested at NERCC, or as part of the Iron Range Resources and Rehabilitation Board (IRRRB) demonstration projects, have included in-ground sand filters (single-pass and recirculating), in-ground peat filters (single-pass), granular peat filters, subsurface flow constructed wetlands, a textile filter coupled with polishing sand filter and shallow dispersal trenches, an aerobic treatment unit coupled with drip distribution, standard infiltrative trenches, a gravel filter and drip distribution (McCarthy et al., 1997, 1998, 1999, 2001; Henneck et al., 1999, 2001; Axler et al., 1999, 2000; Monson Geerts et al., 2000, 2001; Pundsack et al., 2000, 2001). This report provides an overview of the year-round operation and performance of pre-engineered modular peat filters at the NERCC research facility.

II. System Design and Construction

Two containerized peat biofiltration systems (Bord na Móna - Puraflo®) were installed at NERCC in June 1998 (Figure 1). The objective of the project was to compare the year-round performance of the standard Puraflo® system containing an Irish peat to that of a system containing a specified proprietary Minnesota peat from Minnesota Sphagnum Inc.(MSI). Furthermore, the systems were loaded so that their performance could be compared to other advanced wastewater technologies tested at NERCC at a similar daily flow using the same wastewater. The Puraflo® peat filters were loaded at a daily flow of 250 gal/day using septic tank effluent (STE) at a loading rate of 2.6 gal/ft^2/day.

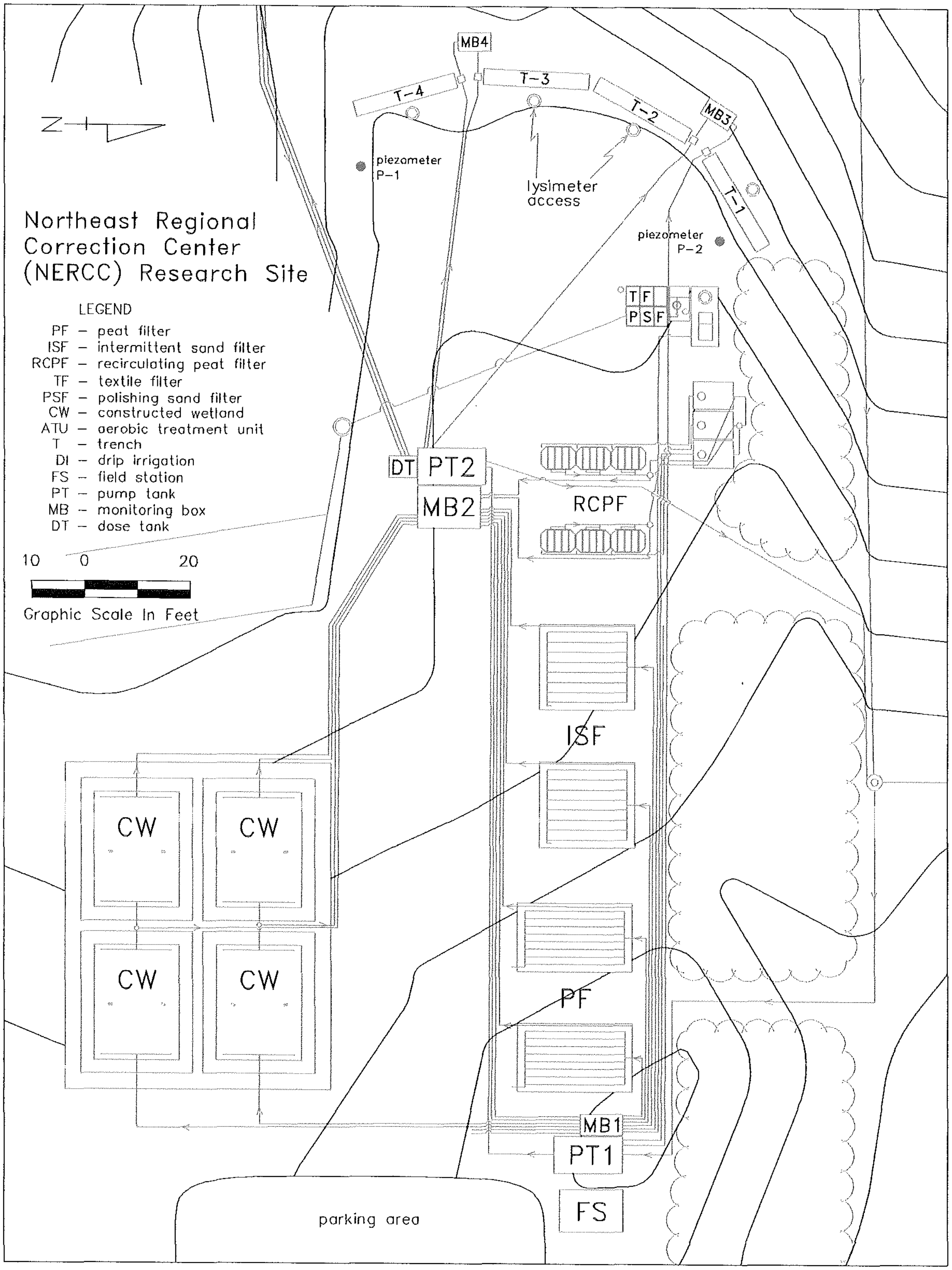
The systems were originally set to run at a 2:1 recirculation mode. Bord na Móna recommends that a residential system include one module per bedroom or up to 150 gal/day using domestic strength wastewater. At a forward flow of 250 gal/day, the control panels were set to dose every 1.5 hours (16 times/day) for a specific time to pump a total of 500 gal/day to each set of modules. At a 2:1 recirculation rate, about half of the peat filter effluent would exit the system and half would be returned to the dose tank. Three modules per system were therefore used at NERCC.

Each module consists of a preassembled polyethylene container, approximately 7.1ft.(L) x 4.6ft.(W) x 2.5ft.(D). The modules were placed end-to-end in a shallow, level excavation, containing well drained sandy soils. Both the supply and drain lines were constructed using 2-inch schedule 40 PVC pipe. Flow splitters and dose tanks (1,000 gallon each) were included in the design to recirculate the effluents for additional nitrogen removal. Thermocouples, to monitor temperature, were installed in the modules at the network and 12 inches below the network.

1. <u>Peat characterization</u>

The Irish peat is characterized as a fibric graminoid peat and consists of 78 to 83% graminoid fiber (*Eriophorum vaginatum*), 0 to 5% partly decomposed mosses, 16 to 17% partly decomposed *Sphagnum* (90% *S. imbricatum* and 10% *S. papillosum*) and 0 to 1% woody plant material. The Bord na Móna specified peat from MSI is characterized as a fibric *Sphagnum* peat with graminoid, consisting of 5 to 33% graminoid fiber (*Eriophorum spissum*), 0 to 3% partly decomposed mosses, 64 to 86% Sphagnum (nearly all *S. fuscum* and a trace *S. magellanicum*) and 0 to 9% woody plant material.

Figure 1. Plan view of the NERCC Demonstration Site.



2. Construction and equipment

Construction of the Puraflo® systems took place during the week of June 22, 1998 by a local installer under the supervision of a Bord na Móna representative. Three 1,000 gallon concrete septic tanks were installed side-by-side for the Puraflo® systems (Figure 2). The first tank in line (supply tank) receives STE via a pump located in the main head tank (2,500 gallon) and regulated by a float located in one of the two dose tanks. STE flows from the supply tank through a Zabel model A300 effluent filter and is evenly distributed between the two systems dose tanks using a Zeus Z200-D flow divider.

Prior to installation, three modules were assembled at the Minnesota Sphagnum, Inc production facility (Photo 1). Three to four inches of 1-2 inch diameter rock was placed in the bottom of each module for drainage, followed by coarse peat screenings placed in 12 inch lifts. The lifts were packed under foot to a level just below the top of the module. A 1.25-inch PVC distribution network was suspended from the lateral supports near the top of each module (Photo 2). The network has 10 evenly spaced 0.5-inch openings at 3 and 9 o'clock, covered with orifice shields. Between 6-8 inches of peat was placed over the distribution network and the lid was bolted down. The modules containing standard Irish medium were assembled at Bord na Móna's facility in North Carolina.

Two shallow, level excavations each 25ft.(L) x 5ft.(W) x 1ft.(D) were prepared for placement of the modules. Approximately 6 inches of clean coarse sand was placed in each excavation and leveled using a laser. Three modules were placed, end-to-end, in each excavation using a backhoe and nylon lifting straps (Photo 3). The modules were aligned so that they all drained to one side. The supply and drain lines connecting the modules were installed using 2-inch schedule 40 PVC pipe (Photo 4). A flexible pipe was used to make connections to the module to prevent separation as a result of frost heaving and settlement. The modules and associated piping were backfilled with native soils and seeded to prevent erosion (Photo 5).

Each system is dosed from an independent 1,000 gallon concrete tank using a Zoeller ½ H.P. submersible effluent pump. STE is pumped from the tank, through a GAG Sim/Tech pump-through filter, and through 2-inch PVC pipe to each module. After passing through the peat, effluent collects in the bottom drain rock and flows by gravity out through a drain line. A second Zeus Z200-D flow divider was installed within the 2-inch drain line to return flow back to the dose tank when operated in the recirculation mode. The effluent drains by gravity through a 1.5-inch PVC pipe to the lower monitoring box where outflow volumes are recorded using a tipper bucket and data logger. Effluent samples were collected where the discharge pipe empties into the tipper bucket.

An Orenco Systems® (OSI), model S1 PT control panel was installed for each Puraflo® system, mounted on a treated wood post between the dose tanks. Three floats were attached to a "float tree", including: 1) an enable float switch, which allows the pump to turn on, 2) a high water

Figure 2. Schematic of the NERCC Puraflo® peat filter systems.

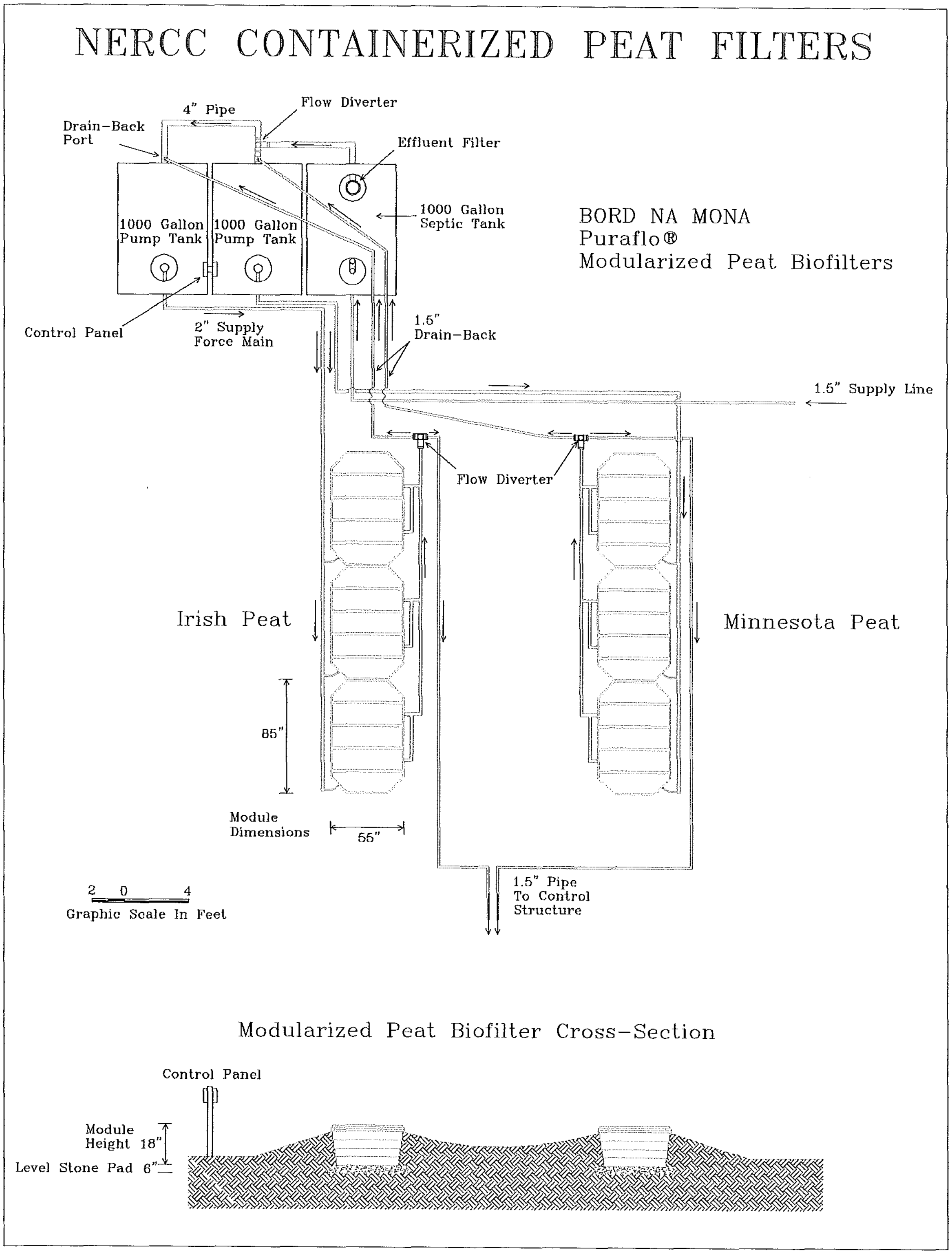


Photo 1. Placement of Minnesota peat medium at MSI.

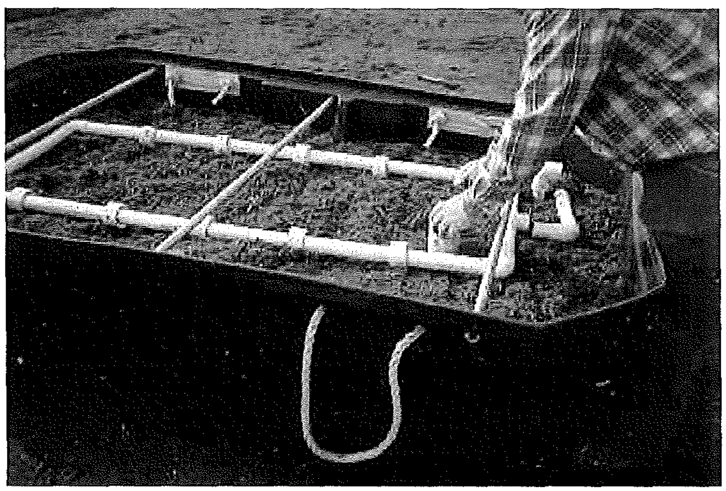


Photo 2. Hanging distribution network from supports.

Photo 3. Module placement in level excavation.

Photo 4. Connecting the modules.

Photo 5. Completed Puraflo® system (3 modules).

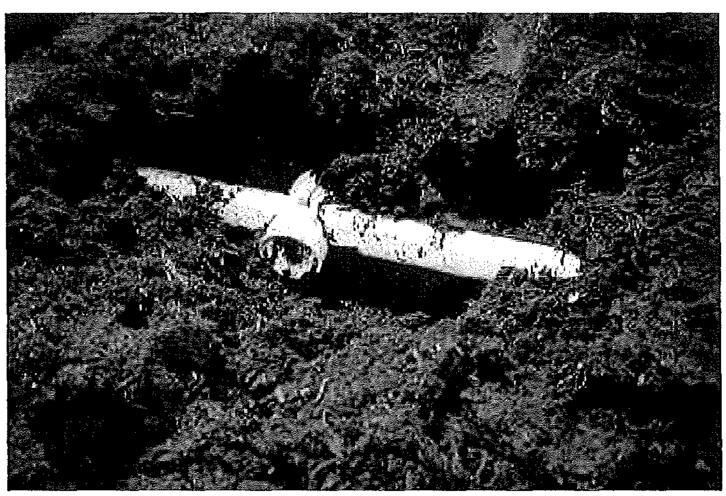


Photo 6. Exposed biomat from hydraulic failure.

alarm float switch, which signals an alarm at the control panel if high water in the tank occurs, and 3) a low water float switch, to prevent pump burn out if water levels drop below the pump. The "float tree" was attached to the tank riser for accessibility and stability.

III. Monitoring Methods

The Puraflo® peat filters, like the other systems at NERCC, were monitored approximately every three weeks. Samples were collected from each system where effluent enters the tipper buckets in the lower monitoring box. The samples were analyzed for total suspended solids (TSS), biochemical oxygen demand (BOD_5), fecal coliforms and total phosphorus (TP) at the Western Lake Superior Sanitary District (WLSSD) (APHA, 1998). All nitrogen (total-N (TN), ammonia-N, and [nitrate+nitrite]-N), pH, and alkalinity were analyzed at the NRRI (APHA,1998; Ameel et al.,1998). Indigenous coliphage viruses were also determined on inflows and outflows (see Axler et al. 2000 for details).

In the field, temperature, conductivity and dissolved oxygen were measured using a YSI85 multi-sensor meter. Flows were determined using elapsed run time counters, event counters and tipper buckets. Thermocouples were installed in three of the six modules to monitor temperature at the distribution network and ~12 inches below the network. The modules with thermocouples included one with Irish peat, one with Minnesota peat, and the third containing a mixed peat (layered Irish + Minnesota peat). In 1999, the performance of a mixed peat filter (Irish + Minnesota peat) module was added.

IV. Performance Results

The peat filters became operational in June 1998. The systems were operated initially as recirculating filters from June 1998 to April 1999 and later as single-pass filters from May 1999 to May 2001.

The following section of the report summarizes the operation and performance of the Puraflo® peat filters by peat type (Irish, MSI and mix), mode of operation (recirculation and single-pass) and season (winter and summer). During the monitoring period, incoming STE from the correctional facility was fairly strong for both BOD_5 (262-335 mg/L) and TN (92-104 mg/L). Typical residential strength effluent is reported to range between 150-250 mg/L for BOD_5 and 50-90 mg/L for TN (Crites and Tchobanoglaus, 1998). In an attempt to dilute the effluent, incoming STE was mixed with fresh water in the main head tank beginning in May 2000.

1. <u>Recirculating Peat Filters</u>

A. Irish peat

During the first mode of operation the standard Irish peat (recirculation mode) did an excellent job at removing solids, organic matter and fecal coliform bacteria (Table 1). The target flow of 250 gal/day was met during the winter with average daily flows of 246 gal/day, but fell short during the summer, averaging 182 gal/day. Average effluent TSS was < 7 mg/L (88-97% removal) and BOD_5 was <14 mg/L (96% removal). There was little variation in seasonal removal of BOD_5, although the average organic loading rate varied from 0.63 lbs BOD_5/day in winter to 0.31 lbs BOD_5/day in summer. The removal of fecal coliform bacteria was better during summer with average fecal levels of 84 cfu/100 mL (99.98% removal) compared with 3302 cfu/100 mL fecals (99.6% removal) during the winter.

Table 1. Performance of Bord Na Móna peat filter using standard Irish peat (recirculating mode) at NERCC, July 1998 through June 1999.

Recirculating (Puraflo®) Peat Filter - Irish Peat (July 1998 - June 1999)						
Parameter	WINTER (Nov. - Apr.)			SUMMER (May - Oct.)		
	Inflow[1]	Outflow[2]	% - Removal[3]	Inflow[1]	Outflow[2]	% - Removal[3]
Q (gal/d)	246			182		
Organic load (lb/d)	0.63			0.31		
TSS (mg/L)	53 (16)	6.5 (5.9)	88	52 (9.3)	1.4 (2.0)	97
BOD_5 (mg/L)	335 (32)	13 (9.6)	96	262 (42)	11 (22)	96
TP (mg/L)	16 (1.1)	15 (1.7)	6	15 (1.4)	12 (1.1)	20
TN (mg/L)	104 (8.1)	69 (15)	34	92 (7.3)	57 (16)	38
NH_4-N (mg/L)	94 (8.1)	33 (25)	65	85 (4.5)	4.4 (8.0)	95
NO_3-N (mg/L)	0.04 (0.04)	34 (21)	(nitrification)	0.02 (0.01)	55 (9.1)	(nitrification)
fecal coliforms[4]	$8.2x10^5$	3302	99.6	$4.0x10^5$	84	99.98
EC25 (umhos)	1398 (46)	951 (165)	32	1270 (45)	777 (108)	39
Temp. (°C)	13 (1.1)	4.2 (1.5)		20 (1.3)	18 (4.0)	
pH	7.29 (0.07)	6.5 (0.4)		7.20 (0.01)	5.5 (0.4)	

Total number of sampling events = 8 winter, 6 summer, between July 1998 and June 1999;
[1]average STE during the seasonal period (± Standard Deviation);
[2]average seasonal values;
[3]mean percent removal based on: ((inflow-outflow)/inflow) x 100 = % removed;
[4]geometric mean colony-forming units (cfu) per 100ml. S.D.'s ($2.3x10^5$), (3809), ($1.3x10^5$) and (120).

The somewhat decreased wintertime performance for TSS, TP and fecal coliforms may have been due to wastewater ponding observed in April 1999. The modules were temporarily shut down and allowed to rest for several weeks. The top12-18 inches of peat was periodically turned to help the peat dry out. The systems were then operated as single-pass systems beginning May 1999. While the Irish peat filters fully recovered, the modules containing Minnesota peat ponded a second time about a month later. The Minnesota peat was removed from the modules and they were re-constructed later in the summer. Nitrification, as indicated by the production of nitrate, was substantially lower in winter also. This was also observed previously in the single-pass sand and peat filters over the period 1996-2001 and was most likely a temperature effect (McCarthy et al. 1998, 1999; Tchobanoglaus and Schroeder 1987).

The Irish peat removed a minimal amount of phosphorus, with slightly better TP removal during the summer (20% removal) following start-up when the peat was new, than during the first winter (6%TP removal). Total nitrogen removal approached 40% in the recirculation mode, and because of the high incoming nitrogen (92-104 mg/L TN), effluent levels remained high in both summer (57 mg/L) and winter (69 mg/L). The recirculating peat filter was largely aerobic during the summer, but less so during the winter. This resulted in highly nitrified (95%) effluent (55 mgNO_3/L) with little ammonium (<5 mg/L). The level of nitrification decreased from 95% in summer to 65% in winter, associated with a corresponding increase in NH_4-N from <5 mg/L to 33 mg/L. The data indicates that the recirculating Irish peat modules were nearly saturated or ponded during the winter, which probably began in December 1998 at the onset of cold air (-15°C) and lack of insulation. The cold temperatures coupled with the high strength waste (BOD_5 and TN), created a large demand for oxygen, along with high hydraulic loading rates, contributed to its failure.

B. Minnesota peat

The performance of Minnesota peat in the recirculation mode was comparable to that of the standard Irish peat, although the flows were slightly different (Table 2). In the winter, average flow to the Minnesota peat (296 gal/day) was 56 gal/day greater than to the Irish peat, while there was little difference (~7 gal/day) between the two systems in summer. Average TSS was <8 mg/L (86% and 94% removal) for both seasons, but effluent BOD_5 from the Minnesota peat filter varied seasonally, with 9 mg/L BOD_5 (97% removal) in summer and 20 mg/L BOD_5 (94% removal) in winter.

Pathogen reduction performance of the Puraflo® recirculating filter using Minnesota peat exceeded 96% removal, although fecal coliform bacteria levels were still high during the winter (30,000 cfu/100mL), typical of recirculating sand and gravel filters (Roy and Dube, 1994; Christopherson et al., 2001; Martinson et al., 2001) in cold climates. We suspect that the high wintertime bacterial levels were likely due to the cold weather problems previously described. Like the Irish peat, the Minnesota peat performed better during the summer and reduced fecal coliforms to 238 cfu/100mL (99.9% removal). The Irish peat had comparable levels at 84 cfu/100mL (99.98% removal).

Phosphorus removal by the Minnesota peat followed a similar trend as the Irish peat during the first summer (both peat types removed 20% TP), but the Minnesota peat slightly out-performed the Irish peat during the first winter with13% TP removal versus 6% TP removal by the Irish peat, despite the higher wintertime flows to modules using Minnesota peat. Nitrogen removal using the Minnesota peat followed a similar trend as the standard Irish peat, with better nitrogen removal in summer (45% TN removal) than winter (31% TN removal). Likewise, there was a higher level of nitrification in summer (78% nitrification) compared with winter (41%

nitrification).

The difference in nitrogen removal between the two peat types (recirculation mode) was small, with the Irish peat performing slightly better in winter and the Minnesota peat performing better in summer. Year-round, nitrification was greater using the Irish peat, indicating that oxygen and/or temperature were likely limiting nitrogen conversion in the Minnesota peat. The lower year-round nitrification rate using Minnesota peat could be explained by several factors, including: 1) cold temperatures and near freezing conditions in winter, resulting in a reduction of biological activity (nitrifying organisms); 2) higher hydraulic loading rate (~30 gal/day/module at 2:1 recycle); and 3) accompanying reduction in oxygen diffusion as a result of saturation/ponding in the modules.

Table 2. Performance of Bord Na Móna peat filter using Minnesota peat (recirculating mode) at NERCC, July 1998 through June 1999.

Recirculating (Puraflo®) Peat Filter - Minnesota Peat (July 1998 - June 1999)						
Parameter	WINTER (Nov. - Apr.)			SUMMER (May - Oct.)		
	Inflow[1]	Outflow[2]	% - Removal[3]	Inflow[1]	Outflow[2]	% - Removal[3]
Q (gal/d)	296			175		
Organic load (lb/d)	0.55			0.44		
TSS (mg/L)	53 (16)	7.4 (5.4)	86	52 (9.3)	3.3 (2.2)	94
BOD_5 (mg/L)	335 (32)	20 (23)	94	262 (42)	9.0 (8.5)	97
TP (mg/L)	16 (1.1)	14 (1.3)	13	15 (1.4)	12 (0.5)	20
TN (mg/L)	104 (8.1)	72 (17)	31	92 (7.3)	51 (10)	45
NH_4-N (mg/L)	94 (8.1)	55 (34)	41	85 (4.5)	19 (23)	78
NO_3-N (mg/L)	0.04 (0.04)	19 (21)	(part. nitrif.)	0.02 (0.01)	33 (15)	(nitrification)
fecal coliforms[4]	$8.2x10^5$	$3.0x10^4$	96.4	$4.0x10^5$	238	99.9
EC25 (umhos)	1398 (46)	1039 (203)	26	1270 (45)	660 (96)	48
Temp. (°C)	13 (1.1)	4.1 (1.5)		20 (1.3)	17 (4.0)	
pH	7.29 (0.07)	6.6 (0.7)		7.20 (0.01)	6.0 (0.7)	

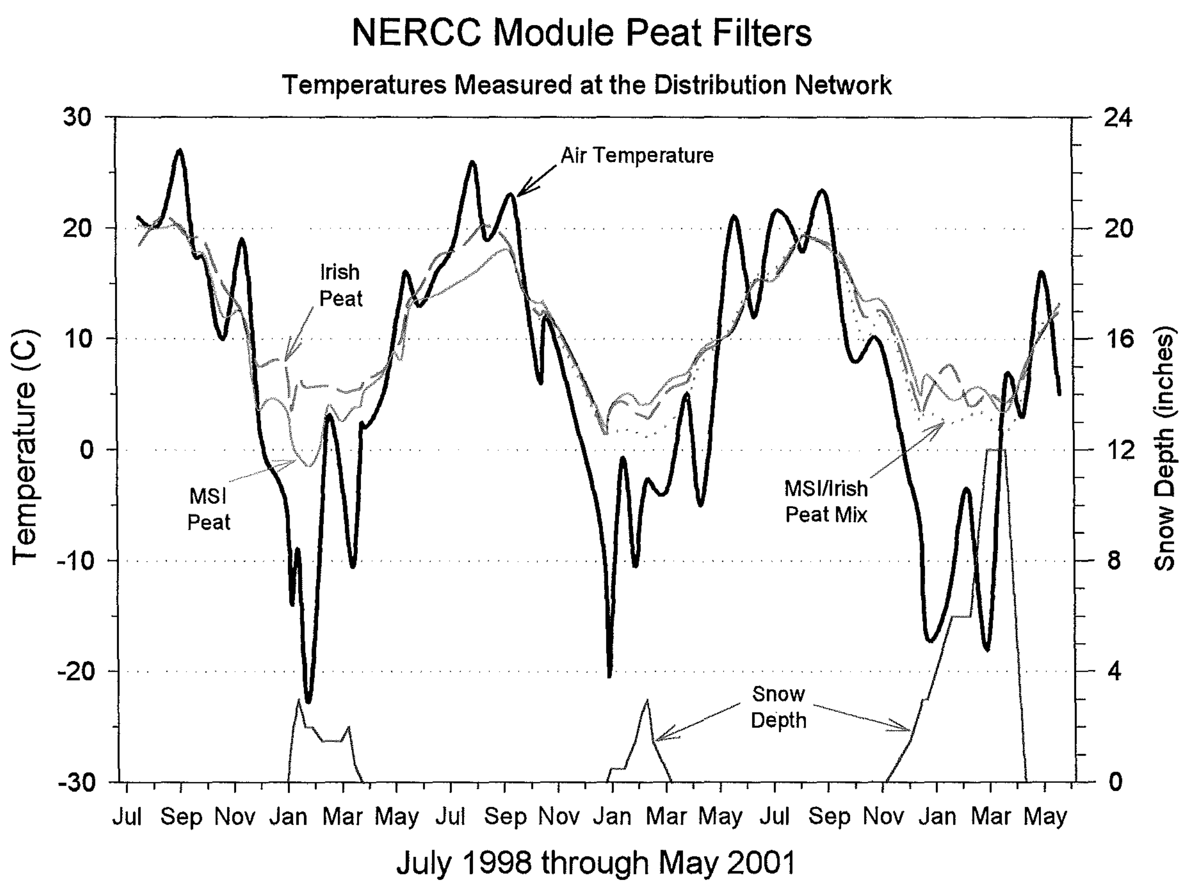
Total number of sampling events = 8 winter, 6 summer, between July 1998 and June 1999;
[1]average STE during the seasonal period (± Standard Deviation);
[2]average seasonal values;
[3]mean percent removal based on: ((inflow-outflow)/inflow) x 100 = % removed;
[4]geometric mean colony-forming units (cfu) per 100ml. S.D.'s ($2.3x10^5$), ($3.1x10^4$), ($1.3x10^5$) and (310).

C. Cold weather operational problems

Performance of the Puraflo® systems began to decline in December 1998, which coincided with the three coldest weeks of the winter, a lack of snow cover and increasing waste strength (BOD_5 $\geq$ 350 mg/L). Snow cover in northeast Minnesota typically helps to insulate onsite systems and prevents systems from freezing. The modules had little frost protection during the period because of the following: 1) lack of snow cover, 2) lack of insulated lids, 3) the modules were only partially buried, and the sidewalls and top were exposed to the elements, and 4) the modules were placed on a wind-blown, west-facing slope with little ability to accumulate snow. Consequently, the modules were left with little protection from the cold.

During the three-week cold snap in December1998 and January 1999, temperatures below freezing were recorded at the distribution network and ~4 °C at 12 inches below the distribution network (Figure 3). Due to an extended cold snap and no snow in the forecast, 2-inch extruded polystyrene was placed on top of the modules in mid-January 1999. Snow was placed around the modules to cover the exposed sides. Within a few weeks, temperature in the modules rebounded to above freezing. It was during this period that the poorest performance occurred, as would be expected.

Figure 3. Internal temperatures of the module peat filters at NERCC.



D. First-year system modifications

In April 1999, insulation was removed from the modules, at which time ponding was observed in both sets of Puraflo® systems. The lids were removed from the modules and the systems were shut down for ~10 days. During this time, the peat was turned with a pitch fork and allowed to dry. Although both sets of modules were ponded, the failure was more pronounced in the modules using Minnesota peat, which had obvious biomat development near the network orifices (Photo 6). Once the peat in both sets of modules was sufficiently dry/fluffed-up, the systems were turned back on.

The Puraflo® system using Irish peat fully recovered and performed well after the event. However, the modules containing Minnesota peat ponded a second time in May. This system was shut down while the modules with Irish peat continued to function in the single-pass mode. In August 1999, the modules containing Minnesota peat were reconstructed. Besides the easily recognized biomat at the network, fine particles of peat had accumulated in the under drain rock, which probably restricted drainage from the module and contributed to its hydraulic failure. The modules were modified by adding additional clean 1.5 inch-diameter rock and drain tile to the bottom of the module and placing new peat in the modules without any foot compaction. Insulated covers were added to all six modules (including the standard Irish peat modules), with each cover sprayed with 1.5 inches of foam at the North Carolina assembly plant.

One of the three modules was filled with a mix of Minnesota and Irish peat, placed in alternating layers (~8 inches) and hand tamped until the module was filled. A separate 1.5-inch discharge line from the module to the tipper bucket was installed to monitor outflow. In an attempt to dilute the high-strength effluent, incoming STE was mixed with fresh water in the main head tank in spring of 2000.

2. Single-pass Operation

A. Irish peat

In the single-pass mode, the Irish peat effectively reduced solids, organic matter and pathogens to very low levels (Table 3). The average flow was 242 gal/day in winter and 223 gal/day in summer during the period June 1999 thru June 2001. The average organic loading rates varied from 0.53 lbs/day BOD_5 in winter to 0.44 lbs/day BOD_5 in summer. Effluent TSS and BOD_5 were both ≤6 mg/L year-round. Fecal coliform bacteria reductions were excellent, with better removal in summer (154 fecal cfu/100 mL) than winter (2454 cfu/100mL).

Monitoring of indigenous coliphages began in 1999. Coliphages are a group of microorganisms commonly found in the human 'gut' and thus, in wastewater. Coliphages are viruses (bacteriophages) that infect and replicate in the bacterium *Escherichia coli (E. coli)*. The unique feature about coliphages is that they are similar in size and shape to human enteric viruses, such as polio virus and hepatitis A. Although the bacterial group 'fecal coliform bacteria' are routinely used as indicators of fecal contamination, coliphages may be better indicators of viral contamination because of their similar size, shape and resistence to disinfection (Gerba, 1987).

Coliphages were detected in the NERCC facility STE and ranged from 200 to 9720 pfu/mL over two years, during the period July 1999 through May 2001. The Irish peat provided good removal of coliphages with 99.8% removal in summer (< 7 pfu/mL) and 97.4% in winter (37 pfu/mL).

During the two years of monitoring (single-pass), the Irish peat exhibited poor phosphorus removal (<10% over the period of monitoring). Nitrogen (TN) removal was slightly better in winter (36 % TN removal) than summer (24 % TN removal), with >80% nitrified after passing through Irish peat. Nitrate-N in peat filter effluent was fairly high at 38-59 mg/L NO_3-N but NH_4-N was low (3-11 mg/L NH_4-N).

Table 3. Performance of Bord Na Móna peat filter using standard Irish peat (single-pass mode) at NERCC, June 1999 through June 2001.

Single-pass (Puraflo®) Peat Filter - Irish Peat (June 1999 - June 2001)						
Parameter	WINTER (Nov. - Apr.)			SUMMER (May - Oct.)		
	Inflow[1]	Outflow[2]	% - Removal[3]	Inflow[1]	Outflow[2]	% - Removal[3]
Q (gal/d)	242			223		
Organic load (lb/d)	0.53			0.44		
TSS (mg/L)	44 (13)	3.7 (4.5)	92	56 (18)	2.5 (2.3)	96
BOD_5 (mg/L)	262 (60)	6.4 (7.5)	98	236 (66)	5.1 (3.5)	98
TP (mg/L)	14 (2.2)	12 (2.4)	14	15 (4.4)	15 (4.4)	0
TN (mg/L)	76 (19)	49 (10)	36	82 (21)	62 (16)	24
NH_4-N (mg/L)	70 (14)	11 (10)	84	71 (19)	2.9 (5.2)	96
NO_3-N (mg/L)	0.02 (0.01)	38 (15)	(nitrification)	0.02 (0.01)	59 (15)	(nitrification)
fecal coliforms[4]	$5.2x10^5$	2454	99.5	$4.1x10^5$	154	99.96
Coliphage[5]	1404 (1478)	37 (49)	97.4	3112 (3663)	6.4 (18)	99.8
EC25 (umhos)	995 (295)	611 (174)	39	1073 (288)	756 (208)	30
Temp. (°C)	12 (1.8)	4.5 (2.8)		17 (3.4)	16 (3.6)	
pH	7.19 (0.26)	6.2 (0.3)		7.28 (0.07)	6.6 (0.4)	
DO (mg/L)	0.56 (0.49)	6.6 (1.2)		0.35 (0.76)	5.1 (1.5)	

Total number of sampling events = 16 winter, 18 summer, between June 1999 and June 2001;
[1]average STE during the seasonal period (± Standard Deviation);
[2]average seasonal values;
[3]mean percent removal based on: ((inflow-outflow)/inflow) x 100 = % removed;
[4]geometric mean colony-forming units (cfu) per 100ml. S.D.'s ($5.6x10^5$), (4399), ($2.8x10^5$) and (345);
[5]geometric mean plaque-forming units (pfu) per mL, N = 16 winter, 15 summer, June 1999-June 2001.

In summary, the Irish peat operating as single-pass and recirculating filters, removed 97% BOD_5 and10 % TP year-round, with little performance difference between the operational modes. The Irish peat removed slightly more nitrogen (36%TN) in the recirculating mode as compared to 30% TN removal in the single-pass mode.

B. Minnesota peat

In the single-pass mode, the Minnesota peat was also effective at reducing solids, organic matter and pathogens (Table 4). Average flow was 250 gal/day in winter and 223 gal/day in summer, September 1999 thru June 2001. The average organic loading was 0.55 lbs BOD_5/day in winter and 0.44 lbs BOD_5/day in summer. Effluent TSS was ≤5 mg/L, while BOD_5 was 5 mg/L in summer and 13 mg/L in winter. Fecal coliform bacteria removal was moderate, with slightly better removal in summer (1625 fecal cfu/100 mL) than winter (4833 cfu/100mL).

Table 4. Performance of Bord Na Móna peat filter using Minnesota peat (single-pass mode) at NERCC, September 1999 through June 2001.

Single-pass (Puraflo®) Peat Filter - Minnesota Peat (September 1999 - June 2001)						
Parameter	WINTER (Nov. - Apr.)			SUMMER (May - Oct.)		
	Inflow[1]	Outflow[2]	% - Removal[3]	Inflow[1]	Outflow[2]	% - Removal[3]
Q (gal/d)	250			223		
Organic load (lb/d)	0.55			0.44		
TSS (mg/L)	44 (13)	4.9 (2.1)	89	56 (18)	3.1 (1.9)	94
BOD_5 (mg/L)	262 (60)	13 (8.8)	95	236 (66)	4.9 (3.5)	98
TP (mg/L)	14 (2.2)	12 (2.6)	14	15 (4.4)	12 (2.7)	20
TN (mg/L)	76 (19)	49 (17)	36	82 (21)	52 (9.4)	37
NH_4-N (mg/L)	70 (14)	6.3 (8.2)	91	71 (19)	1.8 (2.9)	97
NO_3-N (mg/L)	0.02 (0.01)	47 (8.6)	(nitrification)	0.02 (0.01)	50 (9.4)	(nitrification)
fecal coliforms[4]	$5.2x10^5$	4833	99.1	$4.1x10^5$	1625	99.6
Coliphage[5]	1404 (1478)	76 (79)	94.6	3112 (3663)	29 (37)	99.1
EC25 (umhos)	995 (295)	566 (145)	43	1073 (288)	725 (250)	32
Temp. (°C)	12 (1.8)	4.5 (2.9)		17 (3.4)	14 (2.9)	
pH	7.19 (0.26)	5.8 (0.3)		7.28 (0.07)	6.3 (0.3)	
DO (mg/L)	0.56 (0.49)	6.8 (1.0)		0.35 (0.76)	5.6 (1.4)	

Total number of sampling events = 16 winter, 12 summer, between September 1999 and June 2001;
[1]average STE during the seasonal period (± Standard Deviation);
[2]average seasonal values;
[3]mean percent removal based on: ((inflow-outflow)/inflow) x 100 = % removed;
[4]geometric mean colony-forming units (cfu) per 100ml. S.D.'s ($5.6x10^5$), (6962), ($2.8x10^5$) and (2874);
[5]geometric mean plaque-forming units (pfu) per mL, N = 16 winter, 15 summer, between June 1999 and June 2001.

Coliphages (geometric mean) in the STE ranged from 1404 to 3112 pfu/mL, September 1999 through June 2001. The Minnesota peat provided good removal of coliphages (>94%), with slightly better performance in summer (99.1% to 29 pfu/mL) than winter (94.6% to 76 pfu/mL). The Irish peat had a slight advantage over the Minnesota peat in pathogen removal using either group of indicator organisms.

Over a period of almost two years, the Minnesota peat removed 14-20% TP and ~36 % TN. Most of the nitrogen was nitrified; 91% nitrified (winter) and 97% nitrified (summer). Effluent NO_3-N was high (47-50 mg/L NO_3-N) while NH_4-N levels were low (2-7 mg/L).

In summary, the Minnesota peat used in the Bord na Móna modules as both single-pass and recirculating filters removed an average 96% BOD_5 and 17% TP year-round, with little difference between the two operational modes. The Minnesota peat removed 36% of the TN in the single-pass mode and 54% in the recirculating mode.

C. Layered Irish + Minnesota peat

In the single-pass mode, the layered peats (Irish and Minnesota) were also effective at reducing solids, organic matter and pathogens to low levels (Table 5). Since the module with layered peat

Table 5. Performance of Bord Na Móna peat filter using layered Irish and Minnesota peat (single-pass mode) at NERCC, September 1999 through June 2001.

Single-pass (Puraflo®) Peat Filter - Irish + Minnesota Peat (September 1999 - June 2001)						
Parameter	WINTER (Nov. - Apr.)			SUMMER (May - Oct.)		
	Inflow[1]	Outflow[2]	% - Removal[3]	Inflow[1]	Outflow[2]	% - Removal[3]
Q (gal/d)	250			223		
Organic load (lb/d)	0.55			0.44		
TSS (mg/L)	44 (13)	3.8 (2.7)	91	56 (18)	2.9 (2.1)	95
BOD_5 (mg/L)	262 (60)	11 (7.6)	96	236 (66)	4.6 (5.6)	98
TP (mg/L)	14 (2.2)	12 (2.7)	14	15 (4.4)	12 (2.5)	20
TN (mg/L)	76 (19)	52 (12)	32	82 (21)	52 (8.4)	37
NH_4-N (mg/L)	70 (14)	5.9 (5.5)	92	71 (19)	1.1 (1.9)	98
NO_3-N (mg/L)	0.02 (0.01)	47 (9.6)	(nitrification)	0.02 (0.01)	51 (8.5)	(nitrification)
fecal coliforms[4]	$5.2x10^5$	3262	99.4	$4.1x10^5$	294	99.9
Coliphage[5]	1404 (1478)	55 (82)	96.1	3112 (3663)	23 (35)	99.3
EC25 (umhos)	995 (295)	578 (121)	42	1073 (288)	634 (121)	41
Temp. (°C)	12 (1.8)	4.3 (3.0)		17 (3.4)	13 (5.2)	
pH	7.19 (0.26)	6.3 (0.1)		7.28 (0.07)	6.7 (0.1)	
DO (mg/L)	0.56 (0.49)	7.7 (1.3)		0.35 (0.76)	5.2 (0.9)	

Total number of sampling events = 16 winter, 12 summer, between September 1999 and June 2001;
[1]average STE during the seasonal period (± Standard Deviation);
[2]average seasonal values;
[3]mean percent removal based on: ((inflow-outflow)/inflow) x 100 = % removed;
[4]geometric mean colony-forming units (cfu) per 100ml. S.D.'s ($5.6x10^5$), (4546), ($2.8x10^5$) and (166);
[5]geometric mean plaque-forming units (pfu) per mL, N = 16 winter, 15 summer, between June 1999 and June 2001.

was one of the three Minnesota peat modules, the average flows were the same as the modules containing only Minnesota peat, 250 gal/day in winter and 223 gal/day in summer. The organic loading was also the same at 0.55 lbs BOD_5/day in winter and 0.44 lbs BOD_5/day in summer. Effluent TSS was < 4 mg/L, while BOD_5 was < 5 mg/L in summer and 11 mg/L in winter.

Fecal coliform bacteria reduction was good using the layered peat, with better performance in summer (294 fecal cfu/100 mL) than winter (3262 cfu/100mL). The layered peat also provided good removal of coliphages, with slightly better performance in summer (99.3% to 23 pfu/mL) than winter (96.1% to 55 pfu/mL), similar to the reductions using fecal coliform bacteria.

The layered peat removed 14-20% TP, the same TP removal as using just Minnesota peat. Nitrogen removal varied little (32-37% TN removal) between winter and summer. Over 90% of the nitrogen was nitrified after passing through the layered peat, with a slightly better nitrification rate in summer, presumably due to warmer temperatures. Effluent NO_3-N remained high (47-51 mg/L NO_3-N) while NH_4-N levels were low (1-6 mg/L).

In summary, the layered peat used in one Puraflo® module and operated as a single-pass filter, removed an annual average 97% BOD_5, 17% TP and 34% TN. The layered peat was not operated in the recirculating mode.

V. Operation and Maintenance Requirements

Operation and maintenance requirements of the Puraflo® peat filter system are specified in the "Operation and Maintenance Manual for Single Family Homes- Puraflo® peat Biofilters for Wastewater Treatment." Like a car, the system needs to be operated properly and periodically maintained by qualified personnel, to ensure that the system will work to treat wastewater generated in the home and recycle it back into the environment. Although maintenance requirements are fairly simple, it needs to be done. With proper operation by the homeowner and ongoing maintenance by a qualified person, the sewage treatment system will last a long time. Otherwise, the system will break, much like a car if not properly maintained. The following are some of the maintenance and monitoring requirements that need to be performed on component parts of a peat filter system: septic tank, effluent screen, pump tank and pump, control panel, peat modules and soil dispersal system.

1. <u>Septic Tank and Pump Tank</u>

- Flow to the system (water meter in the house)
- Wastewater levels in the tanks
- Water tightness of tanks, risers, and pipe connections at tanks
- Septic tank outlet screen or screened pump vault for clogging
- Condition of tank baffles
- Sludge and scum levels in the septic tanks

- Sludge and grease presence in the pump tank

2. Control panel and controls

- Pumping frequency from pump counters and elapsed run time meters
- Operation of pumps, floats, valves, electrical controls and alarms
- Pump delivery rate (draw down test)
- Dosing volume and measure or calculate average pump run time

3. Peat filter modules

- Excessive moisture and ponding in or leakage from the modules
- Structural damage
- Adequate ventilation around the module lids
- Unusual odor
- Insect infestations
- Sample of peat filter effluent to check for clarity and odor or analyzed as specified in an Operating Permit (i.e.: dissolved oxygen and/or BOD_5)

4. Soil dispersal system

- Excessive vegetative growth over the system
- Extent of ponding
- Wet areas or surfacing of effluent

This list is not meant to be all inclusive of required operation, maintenance and monitoring of a Puraflo® peat filter and soil dispersal system. The most up-to-date product literature from Bord na Móna should be consulted in preparing operating permits for individual systems.

VI. Summary and Conclusions

The NERCC research site provided an excellent location to evaluate the first Puraflo® peat filter systems in Minnesota. Our third party monitoring provides the onsite wastewater treatment industry, local and state regulators, contractors and interested homeowners, with an unbiased evaluation of year-round treatment and operational performance of this peat filter system, especially in a cold climate. Further, in the interest of developing another value-added product for Minnesota peat, this evaluation should provide Bord na Mona with year-round performance data regarding the suitability of Minnesota peat as a possible substitute for the standard peat imported from Ireland.

Standard Irish peat

The standard Irish peat did an excellent job at removing TSS, BOD_5 and fecal coliform bacteria, in both the single-pass and recirculating modes for three years. TSS was typically <8 mg/L and BOD_5 was <14 mg/L. Fecal coliform bacteria reductions were better during the warmer times of the year (84-154 cfu/100 mL) than during the winter (2454-3302 cfu/100 mL). Coliphage reductions were similar to reductions in fecal coliform bacteria, with slightly better performance in summer (7 pfu/mL) than winter (37 pfu/mL).

Phosphorus (TP) removal generally decreased over the three years of monitoring from 20% removal the first summer to <6% removal. In the recirculation mode, nitrogen (TN) removal ranged from 34-38%, with little seasonal difference. As expected, TN removal dropped when operated as a single-pass filter (24-36%) with more apparent variation in removal rate between the seasons. Further, the level of nitrification exceeded 95% in summer in both operational modes. Nitrate-N was the dominant nitrogen form in the effluent (34-59 mg/L) while ammonium-nitrogen was low, except during the first winter when performance was compromised due to inadequate insulation.

Minnesota peat

The Minnesota peat used in the Puraflo® modules was effective at reducing solids, organic matter and pathogens, except during a period of extreme cold the first winter when operated as a recirculating filter. Generally, TSS was <8 mg/L and BOD_5 was <20 mg/L BOD_5. The Irish peat showed a slight advantage over the Minnesota peat in pathogen removal using both groups of indicator organisms. Fecal coliform removal using Minnesota peat was better in summer (<1650 cfu/100mL) than winter (> 4500 cfu/100mL). The highest winter BOD_5 and bacterial levels were likely due to cold weather related problems that first winter. Coliphage removal exceeded 94% in the single-pass mode, with better performance in summer (29 pfu/mL) than winter (76 pfu/mL).

The Minnesota peat slightly out performed the Irish peat in both phosphorus and nitrogen removal, perhaps due to its replacement after the first year of operation or fines and/or iron content in the peat. In the recirculation mode, nitrogen (TN) removal ranged from 31-45%, with greater reductions the first summer. TN removal dropped only slightly (36-37%) when operated as a single-pass filter and there was little difference in its removal seasonally. When operated as a single-pass filter, most of the nitrogen was nitrified (>90%) with effluent levels of ~50 mg/L NO_3-N. In the recirculation mode the first winter, nitrification was limited, probably the result of cold temperatures and lack of insulation to buffer the system from the cold.

Layered Irish and Minnesota peat

The layered Irish and Minnesota peat were also effective at reducing solids, organic matter and pathogens in the single-pass mode. Effluent TSS was <5 mg/L and BOD_5 was <12 mg/L year-round. Fecal coliform bacterial reductions were better in summer (294 fecal cfu/100 mL) than winter (3262 cfu/100mL). Coliphages followed a similar trend. Phosphorus removal was low (14-20% TP removed) while nitrogen removal was consistent (32-37% TN removal) between winter and summer in the single-pass mode. Over 90% of the nitrogen was nitrified, with slightly better nitrification in summer, presumably due to warmer temperatures. Effluent NO_3-N remained high at ~ 50 mg/L NO_3-N. The layered peat was not tested in the recirculating mode.

Cold-weather operational difficulties

The only major operational problem was during the first winter when the modules experienced near freezing conditions during a period of extreme cold and no snow cover. The modules were insulated and temperatures rebounded within a few weeks. However, ponding in both sets of modules was discovered during the spring snow melt and the extent of ponding was more prominent in the Minnesota peat modules. Both sets of modules were rested, allowed to dry for several weeks and then operated as single-pass filters. The standard Irish peat fully recovered but the Minnesota peat hydraulically failed a second time. A combination of cold temperatures, the relatively high strength waste (BOD_5 and TN) and the high hydraulic loading rates when operated in the recirculation mode, all likely contributed to ponding in the modules.

Overall, the Puraflo® peat filter systems performed well at NERCC despite the cold weather problems the first winter that were eventually resolved. The modules are now routinely fabricated with foam-insulated covers. The Minnesota peat performed best when placed in the modules with minimal compaction.

Modular peat filters are one of several types of onsite wastewater treatment systems tested in Minnesota since 1995. Other systems include in-ground single-pass sand filters (McCarthy et al., 1997, 1998, 1999; Anderson et al., 1998; Pundsack et al., 2000, 2001), recirculating sand filters (Christopherson et al., 2001), recirculating gravel filters (McCarthy et al., 1998), in-ground peat filters (McCarthy et al., 1997, 1998; Monson Geerts et al., 2000, 2001; Pundsack et al., 2001), constructed wetlands (Axler et al.,1999, 2000; Henneck et al., 1999, 2000; Pundsack et al., 2001), aerobic treatment units (McCarthy et al., 2001), a textile filter coupled with a polishing sand filter and shallow trench system (McCarthy et al., 2001) and drip distribution. The web site located at http://www.bae.umn.edu/septic/LCMR provides a compilation of these and other publications from the project.

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