Evaluation of the absorption bed's efficiency under the Ecoflo® Biofilter

Summary of the conference presented by M. Roger Lacasse within the context of the 30th Symposium on wastewater treatment

Premier Tech
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Performance evaluation of the absorption bed located underneath the Ecoflo® Biofilter

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The Ecoflo® Biofilter is a wastewater treatment system designed for the sanitary drainage of decentralized dwellings. Preceded by a septic tank, the chain of treatment comprises a biofiltration unit and a polishing field allowing the treated wastewater to be absorbed by the receptor ground. The Ecoflo® Biofilter performances have been evaluated by numerous organizations (MDDEP, BNQ, NSF, CSTB, etc.) for the last 20 years. All studies have demonstrated that the system produces an effluent with concentrations much lower than the criteria required for an advanced secondary treatment level which is 15 mg /L in TSS and BOD_5, and 50 000 FCU/100 mL in fecal coliforms. However, little data have been collected to this day to assess the efficiency of the absorption bed or of the polishing field receiving the waters treated by the Ecoflo® Biofilter.

Within the process of the approval of the Ecoflo® technology in the State of Virginia, an independent study has been realized from 2003 to 2007 to determined the quality of the waters treated by the system comprising an Ecoflo® Biofilter and a 30 cm thick absorption bed in accordance with the State requirements. This study was directed by Dr Robert Rubin, respected professor emeritus at North Carolina University.

Material and method

The testing protocol includes the monitoring of six different residential sites during an 18 month period for the four types of soils present in Virginia and defined in Table 1. Notice that the types of soils are comparable to the ones defined in the Q-2, r.8 Quebec regulation.

Tableau 1 Types of soils

Virginia		Quebec	
Type of soil	**Permeability (min/cm)**	**Type of soil**	**Permeability (min/cm)**
I	≤ 6	Highly permeable	≤ 4
II	> 6 and ≤ 18	Permeable	≥ 4 and < 25
III	> 18 and ≤ 35		
IV	> 35 and ≤ 47	Little permeable	≥ 25 and < 45

Each site installation comprises a septic tank followed by an Ecoflo® Biofilter and an absorption bed located underneath the biofilter. Three suction lysimeters (High flow porous ceramic cup suction lysimeter model 1920F1-B01M3) have been installed on each site in order to measure the quality of the water upstream of the absorption bed (lysimeter # 3 not illustrated in figure 1), at 30 cm under the absorption bed located just underneath the Ecoflo® Biofilter (lysimeter # 1), and at 3 m downstream of the biofilter (lysimeter # 2). Figure 1 presents a typical installation of the biofilter and the monitoring equipment.

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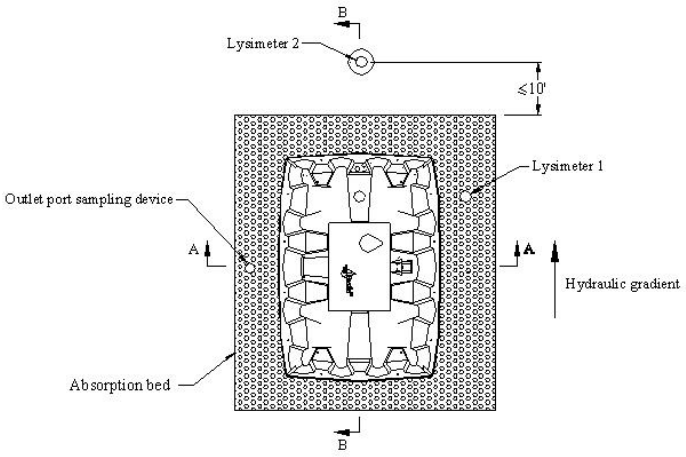
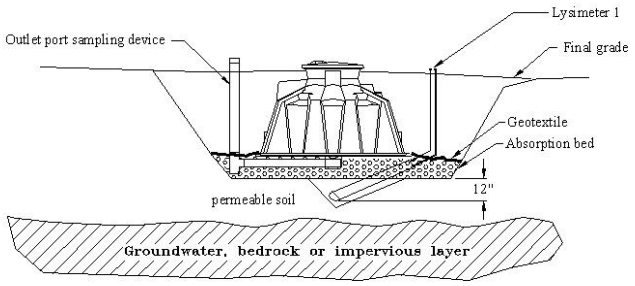
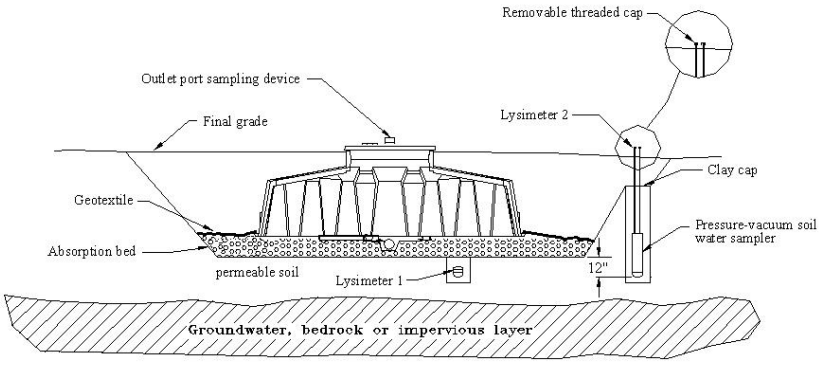


Plan view



Section A-A



Section B-B

Figure 1 Typical installation of the Ecoflo® Biofilter and the monitoring equipment

The sample pick-up has been realized monthly at the septic tank effluent and at the Ecoflo® Biofilter's as well as at the three lysimeters. As per the Virginia regulations, the following parameters have been measured monthly: feeding rate, BOD_5, TSS, fecal coliforms, nitrates and NTK. The sampling of the total phosphorus have been taken three times a year on four sites selected for this purpose, with types of soils I, II and III, and in a sporadic manner on four other sites. Notice should be taken that the BOD_5 and the TSS concentrations were not measured in the lysimeters installed at 30 cm deep (lysimeter # 1) in the ground underneath the biofilters. This situation is due to the fact that the concentrations at the Ecoflo® Biofilter's effluent were much lower than the values required by the State of Virginia's regulations, that is to say, 30 mg/L.

End results

Until now, the monitoring has been completed for 18 sites which are corresponding to soil types I, II and III. The two sites with soil type IV are being monitored presently. The mean flow reached for the sites altogether corresponds to a value of 590 L/d which is the equivalent to the flow rate produced by an average Quebec family (2,3 persons x 270 L/pers.-d or 620 L/d). Beyond that, 90% of the measured values were lower or equal to 942 L/d. Last, it should be noticed that, in some cases, the flow rates have exceeded the capacity of the system with values reaching up to 3 000 L/d. The BOD_5 and TSS concentrations obtained at the Ecoflo® Biofilter's outlet are presented in Table 2. We notice that the biofilter's performances reached during the Virginia monitoring correspond to the values already measured in actual conditions by Premier Tech (PTE) and during the different testings for the certification of the technology.

Table 2 Performances of the Ecoflo® Biofilter in TSS and BOD_5

Parameters	Virginia		PTE's monitoring (11 years, n = 163)		Certification (Ecoflo® effluent)		
	STE	Ecoflo® Effluent	STE	Ecoflo® Effluent ®	CSTB (n = 30)	BNQ (n = 118)	NSF (n = 108)
TSS (mg/L)	34 ± 23 (n = 141)	6 ± 7 (n = 337)	52 ± 48	4 ± 3	5 ± 4	2 ± 0.2	2 ± 0.7
BOD_5 (mg/L)	186 ± 113 (n = 340)	8 ± 8 (n = 337)	176 ± 89	5 ± 5	3 ± 2	2 ± 0.4	2 ± 0.3

The evaluations realized underneath the absorption bed have verified its efficiency at reducing nitrogen, phosphorus and fecal coliforms still present in the effluent treated by the Ecoflo® Biofilter. The mean concentrations measured at the outlet of the different steps of the treatment are presented in Table 3. Table 4 shows the values corresponding to the 90 percentile. The absorption bed composed of a 30 cm layer of soil fed by the Ecoflo® Biofilter's effluent fills the role of completely polishing the treated effluent.

Discussion

Total nitrogen removal

The result analysis presented in Table 3 and 4 demonstrates that the system comprising an Ecoflo® Biofilter and a 30 cm thick absorption bed allows reducing total nitrogen content by 84%. It is important to mention that this performance does not take into account the total nitrogen already present in the groundwater table upstream of the absorption bed (4 ± 4 mg/L). Considering this «background noise», we realize that the total nitrogen concentration at a 30 cm soil depth underneath the biofilter is, in average, lower than 5 mg/L and 12 mg/L for 90% of the results, which respects the mean requirement of 10 mg/L established by different regulations. The values measured in the four soil types do not show any influence on the part of this parameter on the total nitrogen removal efficiency. The performances observed would be imputable to a good nitrification of the wastewater in the biofilter (mean of 80 %) and to the presence of anoxic micro-zones in the soil matrix.

In the presence of soluble carbon coming from the peat base filtering media, these zones would bring favorable conditions to the effluent denitrification.

Table 3 Mean efficiency (± standard deviation) of the Ecoflo® Biofilter and absorption

Parameters	STE	Ecoflo® Effluent	Effluent at 30 cm under the Ecoflo®	Water upstream at 30 cm	Performances		
					Ecoflo®	Absorption bed	Global
N total (mg/L)	45 ± 24 (n = 72)	32 ± 18 (n = 76)	8 ± 9 (n = 77)	4 ± 4 (n = 40)	29%	78%	84%
P total (mg/L)	5,9 ± 0,9 (n = 11)	5,2 ± 0,9 (n = 11)	0,12 ± 0,04 (n = 15)	-	12%	97%	98%
F.C. (CFU/100 mL)	34 262 (n = 51)	1 029 (n = 308)	2 (n = 336)	-	1,5 log	2,7 log	4,2 log

Table 4 Efficiency for the 90 percentile of the Ecoflo®Biofilter and absorption bed

Parameters	STE	Ecoflo® Effluent	Effluent at 30 cm under the Ecoflo®	Water upstream at 30 cm	Performances		
					Ecoflo®	Absorption bed	Global
N total (mg/L)	77	56	22	10	27%	61%	71%
P total (mg/L)	7,1	6,5	0,2	-	8%	97%	97%
F.C. (FCU/100 mL)	240 000	34 300	2	-	0,8 log	4,2 log	5,1 log

Fecal coliforms

We notice that the absorption bed allows fecal coliforms reduction under the detection level of 2 FCU/100 mL and this, for 90% of the results. The 336 values measured are lower than the usual limit of 200 FCU/100 mL, the maximal value corresponding to 170 FCU/100 mL. This attenuation of the fecal coliforms is associated to the retention/fixation phenomenon at the soil particle surface and at the change in physico-chemical conditions of the soils. It is also important to mention that the geometric mean of the fecal coliforms observed at the outlet of the Ecoflo® Biofilter during this study, that is, 1029 FCU/100 mL, corresponds to the results obtained in other monitorings and testings. Indeed, a concentration of 1000 FCU/100 mL has been reached within the context of PTE 's monitoring realized in 1995, of 1250 FCU/100 mL during the BNQ certification testing and of 630 FCU/100 mL at the NSF testing.

Total phosphorus

The performances of the Ecoflo® Biofilter to remove phosphorus are in conformity with the existing data since the beginning of the development of the technology which is a removal in the order of 10 to 15% of total phosphorus in the filtering bed. However, the match-up of the biofilter with a polishing field composed of a layer of at least 30 cm of natural soil, allows the global removal of 98% of the phosphorus present at the septic tank effluent. The total phosphorus mean concentration at a 30 cm depth in the absorption bed equals 0,12 mg/L and 90% of the values are equal or lower than 0,2 mg/L. Remember that the usual disposal criteria corresponds to 1,0 mg/L. These results have been obtained in the soil types I to III installations in operation for more than 40 months and no influence has been noticed with the permeability of the soils used. As per the existing literature, the phosphorus fixation in acid soils is mainly associated with its adsorption to the surface of the metallic elements present in the soil (iron and aluminum). According to Pellerin and al. (2006), the Quebec acid soils, at neutral, can be classified in three groups as far as their ability to retain phosphorus (low capacity: 1,46, mean capacity: 3,04 and high capacity: 5,66 g P/kg of soil). The results have been obtained after analysis of more than 275 soil samplings covering 75 series of soils in a horizon varying between 0 and 70 cm of the surface. Analysis of 25 soil samplings picked-up in different regions of Quebec for the implementation of decentralized sanitary systems indicate comparable results, that is, a retention capacity varying between 0,94 and 5,74 gP / kg of soil (mean of 2,90 gP/kg of soil) and separate from the soil in place permeability. By way of comparison, the analysis of the soils experimented in Virginia present results of the same order which is a retention capacity of the phosphorus of 3 gP/kg of soil for the three soil types used. The access to this phosphorus retention capacity of the soil and the stability of the phosphorus retained, depend on the following main factors: the quality of the effluent infiltrated allowing to prevent clogging of the receptor soil, the withholding of a high redox potential (aerobic) assuring reaction stability with iron and the non saturation of the absorption bed (over the high seasonal groundwater table).

The hydrodynamic and physico-chemical characteristics of the effluent produced by the Ecoflo® Biofilter facilitate phosphorus fixation in the soil. Indeed, the peat base filtering media releases humic and fulvic acids that cause soil particle alteration in the absorption bed, which increase iron and aluminum availability in the soil to react to phosphorus. Also, the low pH conditions prevailing in the filtering media during its start-up phase allow release of iron and aluminum present in the peat, thus creating and additional doping of these metals in the receptor soil. Furthermore, the retention capacity associated with the selected filtering media ensures peak flow attenuation which is translated by a regulation of the flow infiltrated, thus facilitating the non saturation of the soil in the absorption bed. These non saturated conditions are also maximized by the pulsed feeding to the biofilter, by creating repeated wetting/draining cycles bringing air to the soil. Notice that the air present in the gravel area at the base of the biofilter is renewed by the aeration process integrated into the system. Last, to maintain this access to the soil capacity to fix phosphorus, it is essential that the treated effluent to be infiltrated presents an excellent quality in all conditions (variations in flow and in loads, start-up following a prolonged stop, etc.), in order to prevent clogging of the soil by the suspended matter and introduction of too large concentrations of organic matters. These two last factors diminish the redox potential in the soil and reduce soil capacity to fix phosphorus. As demonstrated during testing with particular stresses (NSF, 2005 and BNQ, 2005), the Ecoflo® Biofilter produces an effluent of which the TSS and BOD_5 concentrations fluctuate very little (lower than 5 mg/L) in peak conditions or at start-up after a long period of no feeding. On the basis of the previous data, of the occupancy rate of the residences and of the quantity of phosphorus produced by the occupants, we estimate that the system « Ecoflo® Biofilter + receptor soil » allows retention of the phosphorus produced by a residence for a duration of at least 20 years in the majority of the cases, without taking into account the contribution in iron, aluminum, humic and fulvic acids associated with the filtering media selected.

Conclusion

The results obtained within the context of the independent study realized in the State of Virginia demonstrate an interesting potential for the system comprising an Ecoflo® Biofilter followed by a 30 cm thick layer of soil for the removal of nitrogen, phosphorus and fecal coliforms to levels of usual disposal under 10 mg/L for total nitrogen, 1,0 mg/L for phosphorus and 200 FCU/100 mL for fecal coliforms. In accordance with the recommendations of experts in the decentralized sanitation field (Tchobanouglos, 2003), this study clearly demonstrates the importance of reserving natural soils for the polishing of an effluent having undergone a high level of treatment and presenting little variations. The use of soil for the treatment of primary or secondary effluent presenting variations would not allow exploitation of the full potential for sanitary drainage of this natural matrix. On the basis of these promising results, experimentation goes on to optimize the approach in different conditions, in order to maximize the longevity of the system.

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