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**A BENCH-SCALE SEQUENTIAL AERATED PEAT
BIOFILTER SYSTEM TREATING LANDFILL LEACHATE
UNDER VARIED LOADING RATES**

**BY
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**A Thesis presented to
the Faculty of Graduate Studies and Research
in partial fulfillment of the requirements
for the degree of
Master of Applied Science in Environmental Engineering*
Department of Civil and Environmental Engineering
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Ottawa, Ontario
Canada**

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ABSTRACT

A bench-scale sequential aerated peat biofilter system was developed and evaluated for the treatment of landfill leachate under varying contaminant loading and hydraulic loading rates. This system consisted of two major components: an aeration chamber with an attached growth media and a peat biofilter. In this study, the leachate from the aeration tank, with hydraulic retention times of 5 and 2 days, and constant air flow rate of 3.40 m³/day was fed to two sets of triplicate peat columns, which were operated at average hydraulic loading rates of 8.28 cm³/cm²/day and 10.82 cm³/cm²/day. The result of this study showed that similar organic (COD, CBOD₅) removal performances and life expectancies could be obtained from these two different hydraulic loading rates. However, the higher hydraulic retention times in aeration basin could significantly increased the life expectancy of the peat biofilter by reducing contaminants loading.

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CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

Historically, landfills have been the most economical and environmentally acceptable method for the disposal of solid wastes, both in the United States and throughout the world (Tchobanoglous et al., 1993). Controlled landfilling prevents some of the risks which have been associated with incineration processes. In spite of the number of advantages of using this waste disposal strategy, some inherent concerns exist which include the generation of odors and leachates. As a consequence, the primary issue to deal with when considering landfilling as a solid waste management strategy, is the collection, storage and treatment of, at times, contaminated leachates (Rivas et al., 2003).

The selection and design of a leachate treatment process is not simple, because of the variation in the quality and quantity of leachate from landfill to landfill, and over time, as a particular landfill ages. In addition, the treatment of municipal landfill leachates presents unique problems mainly because of high COD (6000-150,000 mgL⁻¹) and ammonium ion (500-3000 mg L⁻¹) concentrations, high COD/BOD ratios, as well as the presence of hazardous compounds such as heavy metals (Irene and Lo, 1996; Park et al., 2001; Chiang et al., 2001). Hence, due to the complex nature of leachate and increasingly stringent effluent discharge quality standards, neither conventional biological wastewater treatment nor chemical treatment processes separately achieve high removal efficiencies over the life of the landfill (Qasim and Chiang, 1994).

The Trail Road landfill in the City of Ottawa, commissioned in 1980, generates an average rate of 190m³ of leachate per day (Woytowich, 2004). Currently, leachate from Trail Road landfill is hauled by tanker truck for treatment and discharge at the Robert O. Pickard Environmental Center (ROPEC), the City's wastewater treatment facility. However, the concentrations of several contaminants of the leachate exceed or closely approach the City's Sewer Use By-law limit, particularly TKN, TSS, CBOD₅, H₂S, boron, chloride, xylene, toluence, and barium. Therefore, the solid waste disposal facility pays a surcharge for those contaminants that exceed the City Sewer Use By-Law limits. The surcharge is based upon levels of total Kjeldahl nitrogen (TKN), \$4.26 per kg, the parameter with the highest individual fee, and a normal fee of \$0.94 per cubic meter for the treatment of leachate (Woytowich, 2004). An on-site treatment system to pre-treat the landfill leachate could reduce landfilling costs by reducing the surcharge payments, by bringing the landfill to compliance with the Sewer Use By-law limits.

In recent years, many researchers (Heavey, 2003; Kinsley et al., 2003; Kennedy and Van Geel, 2000; Lyons and Reidy, 1997; Talbot et al., 1996; Viraraghavan and Ayyaswami, 1989; Rock et al., 1984) have identified peat as an alternative low-cost filter medium for on-site wastewater treatment including landfill leachate. Besides being plentiful and inexpensive, peat possesses several characteristics that make it a favorable filter medium for contaminant removal, such as high water holding capacity (Bergeron, 1994), low density (Buttler et al., 1994), large surface area (>200 m²/g) (McLellan and Rock, 1988), high porosity (McLellan and Rock, 1988; Buttler et al., 1994; Mitsch and Gosselink, 1993), and excellent ion exchange properties (Sharma and Forster, 1993; McKay, 1996).

The properties of peat depend on several factors, including the ambient conditions existing during its formation, the extent of its decomposition and the method of harvesting (Couillard, 1994). To date, there is limited information in the literature regarding the behavior of peat filter systems under varying contaminant, as well as hydraulic loading rates when operated in a biofilter configuration. In addition, the effect on the treatment efficiencies and on the total operational life of the peat filter systems, of varying contaminant loads, especially organic (COD, BOD₅), ammonia-N, and TSS concentrations, as well as hydraulic loading rates is very important. Therefore, in this research, the removal performance and operational life expectancy of a peat biofilter preceded by an aeration chamber, operated at constant air flow rate of 3.40 m³/d and HRTs of 5 and 2 days, with a support media for the growth of an attached biofilm, were investigated with particular emphasis on different hydraulic and contaminant loading rates under continuous flow condition. The attached growth medium, provided a large active surface area and texture promoting the rapid growth of a biofilm, thus significantly reducing the contaminant loads, especially ammonia-N and BOD₅, on the peat filters, and as a consequence, increased the operational life of the peat biofilter systems.

1.2 RESEARCH OBJECTIVES

The objective of this research was to investigate the removal performance and operational life expectancy of a peat biofilter in terms of organic (COD, CBOD₅), ammonia-N, and TSS constituent and hydraulic loading rates. The combined system consisted of two major components: an aeration chamber with an attached growth media which has a large

surface area and texture promoting rapid growth of biofilm, and two sets of triplicate peat columns operated at different hydraulic loading rates.

In order to reach this objective, the following tasks were undertaken:

1. Determination of the properties of the peat.
2. Operating the aeration chamber with an HRT of 5 days and a constant air flow rate of $3.40 \text{ m}^3/\text{d}$ for a total period of 115 days until the clogging of the peat columns was observed.
3. Operating the aeration chamber with an HRT of 2 days and a constant air flow rate of $3.40 \text{ m}^3/\text{d}$ for a total period of 93 days until the clogging of the peat columns was observed.
4. Operating two sets of triplicate peat columns at an average hydraulic loading rate of $8.28 \text{ cm}^3/\text{cm}^2/\text{day}$ and $10.82 \text{ cm}^3/\text{cm}^2/\text{day}$ in both HRTs 5-day and 2-day.
5. Monitoring water quality parameters: pH, temperature, flow rate, COD, CBOD₅, NH₃-N, NO₃⁻-N, and TSS of raw, aerated leachate, and columns effluents in the 5-day and 2-day HRT studies.
6. As an additional objective, the concentration of H₂S, B and Ba of raw, aerated leachate, and columns effluents were also monitored only in the 2-day HRT.

CHAPTER 2

LITERATURE REVIEW

A thorough literature review was carried out on all aspects of this research work and is presented in the following sections. Since this research is about the treatment of landfill leachate, the information related to landfill leachate was reviewed and is covered in the first section. Treatment methods for landfill leachate, from conventional to innovative, were reviewed and these are presented in section two. Since peat was used as the medium for the treatment system, its characteristics and effectiveness for the removal of contaminants is described in the third section. A summary of all the information is presented in the final section of this chapter.

2.1 LANDFILL LEACHATE

Generally, landfill leachate is defined as a contaminated liquid that percolates through a solid waste disposal site. In most landfills, leachate is composed of the liquid that has entered the landfill from external sources, such as surface drainage, rainfall, groundwater, and water from underground springs and the liquid produced from the decomposition of the wastes (Tchobanoglous et al., 1993). If not managed properly, landfill leachate could potentially contaminate surface and subsurface waters.

The two major concerns associated with landfill leachate are its quality and quantity. The quality of landfill leachate is highly variable from landfill to landfill and depends upon many factors like age of fill, type and depth of solid waste, precipitation, ambient

temperature, water content, compaction, permeability and absorption capacity of the waste. This leachate contains larger pollutant loads than raw sewage and many industrial wastes (Qasim and Chiang, 1994). Similar characteristics have been observed with the Ottawa Trail Road Landfill leachate. The concentration of contaminants approach or exceed the the local Sewer Use By-law discharge limits, which is now becoming a major concern in terms of maintaining an environmentally sustainable waste disposal strategy.

The quantity of leachate generation is another important matter of concern. Since the leachate extracts dissolved or suspended materials from the waste, more water flowing through the solid waste, generally causes more leaching of pollutants. The volume of leachate generation generally depends upon the amount of precipitation, surface runoff and infiltration, evapotranspiration, the volume of ground water entering the landfill, as well as the moisture content and absorption capacity of the waste materials. Leachate generation gradually increases for the first 5 to 10 years because new landfills have high moisture holding capacities, which would retain some of the water that would typically precipitate through an older landfill (Rehman, 2003).

As previously mentioned, the characteristics of landfill leachate depend upon many factors, which are very difficult to correlate with leachate characterization. However, age (i.e. phase) dependent compositions of landfill leachate are available from the literature. The leachate concentrations are frequently reported as ranges, not as discrete values. These ranges are usually quite broad, often spanning several orders of magnitude. Leachate characteristics change through two major phases, an anaerobic acid

(acidogenic) phase followed by a methanogenic phase. Typical constituent concentration ranges for landfill leachates during the acidogenic and methanogenic phases are presented in Table 2-1.

Table 2-1: Typical Characteristics of Landfill Leachate

	Unit	Acidogenic	Not phase dependent	Methanogenic
pH	-	4.5-7.8		6.8-9
BOD ₅	mg O ₂ L ⁻¹	4000-68000		20-1770
COD	mg O ₂ L ⁻¹	6000-152000		500-8000
TOC	mg L ⁻¹	1010-29000		184-2270
VFA (TOC-eq)	mg L ⁻¹	963-22414		<5-146
SO ₄	mg L ⁻¹	<5-1750		<5-420
Ca	mg L ⁻¹	10-6240		20-600
Mg	mg L ⁻¹	25-1150		40-478
Fe	mg L ⁻¹	20-2300		1.6-280
Mn	mg L ⁻¹	0.3-164		0.03-45
Zn	mg L ⁻¹	0.1-140		0.03-6.7
As	µg L ⁻¹		5-1600	
Cd	µg L ⁻¹		0.5-140	
Co	µg L ⁻¹		4-950	
Ni	µg L ⁻¹		20-2050	
Pb	µg L ⁻¹		8-1020	
Cr	µg L ⁻¹		30-1600	
Cu	µg L ⁻¹		4-1400	
Hg	µg L ⁻¹		0.2-50	
Cl	mg L ⁻¹		100-5000	
Na	mg L ⁻¹		50-4000	
K	mg L ⁻¹		10-2500	
Alkalinity	mg CaCO ₃ L ⁻¹		300-11500	
NH ₄ -N	mg L ⁻¹		30-3000	
Org. N	mg L ⁻¹		10-4250	
Total-N	mg L ⁻¹		50-5000	
NO ₃ -N	mg L ⁻¹		0.1-50	
NO ₂ -N	mg L ⁻¹		0-25	
Total-P	mg L ⁻¹		0.1-30	
AOX ^a	µ Cl L ⁻¹		320-3500	

^a Adsorbable organic halogens

Reference: Kylefors et al., 2003; Ehrig, 1989; Robinson and Gronow, 1993.

The Trail Road landfill site mainly receives commercial and residential waste from the City of Ottawa. Leachate from the landfill is a mixture of leachate from new and old landfill area. The characteristics of the Trail Road landfill leachate and the City of Ottawa Sewer Use By-law Limits are presented in Table 2-2. As can be seen, the Trail Road landfill leachate characteristics indicate that most of the phase dependent components of the leachate fall within the methanogenic ranges reported in Table 2-1. Some of the contaminants are not in compliance with the City of Ottawa's Sewer Use By-law limits and the Landfill must pay a surcharge for those contaminants that exceed the limits. In this case, the surcharge levied from the Landfill is based upon concentrations of total Kjeldahl nitrogen (TKN), the parameter of highest individual fee. In addition to TKN, TSS, CBOD₅, H₂S, boron, chloride, xylene, toluence, and barium also exceed or closely approach the Sewer Use By-law limits of the old Regional Municipality of Ottawa-Carleton (RMOC), as well as several of the current and proposed Sewer Use By-law limits for the City of Ottawa.

Table 2-2: Trail Road Landfill Leachate Composition

Constituent	Yearly Composition-Average Value					Sewer Use By-law ^a	
	1998	1999	2000	2001	2002	1999	2004
pH	7.6	7.2	7.59	7.44	7.23	5.5-9.5	5.5-9.5
BOD ₅ *	916		630.7	2337.8	1584	300	300
COD	2194	2659	1493.2	4394.9	2978.2	-	-
TSS*	50	73	38.47	258.31	164.22	350	350
TKN*	664	615	487.88	674.45	621.67	100	100
NO ₃ +NO ₂			1		0.3		-
H ₂ S*	2.0	5.0		1.615	0.817	2	2
SO ₄	6.8		35.25	112.5	37.3	1500	1500
Total-P	4		3.68	2.6	2.54	10	10
PO ₄	3.4						
Cl*	1480		1307.5	1292.5	831.25	1500	-
B*	7.8	4.7	5.35	3.7	3.92	2	-
Na	682		913.25	560	129		
K	660		438.25	245.5	79	-	-
Fe	4.1		13.26	11.95	18.25	50	50
Ca	214		152.5	195.5	249	-	-
Mg	173		106.6	72.5	79.5	-	-
Ba*	1.04	0.66	0.88	0.48	0.83	1.2	-
Zn	0.3		0.62	2.595	0.82	3	3
Al	0.9		6.23	0.155	0.12	50	-
Sr	12.9		10.48	6.9	9.7	5	-

Note: all concentration is in mg/L except pH, which has no units.

Reference: City of Ottawa, 2004; Rehman, 2003; Kinsley et al., 2003

* Contaminants exceeded the Sewer Use By-law limits

^a Dilution cannot be used to meet the limits

2.2 TREATMENT OF LANDFILL LEACHATE

The treatment and management of landfill leachate are becoming more difficult due to increasingly stringent effluent discharge quality standards. The selection and design of a leachate treatment processes are not simple, since there is great variation in the quality and quantity of leachate generated from landfill to landfill, and over time as a particular landfill ages. Conventional treatment systems are costly and require a long-term commitment. Moreover, the large variations in strength and flows of leachate, as well as

its toxic effects because of the presence of high concentrations of heavy metals, ammonia and various organic compounds, make these systems problematic in terms of maintaining effluents discharge limits (Sartaj, 2001; Tchobanoglous et al., 1993; McLellan and Rock, 1988).

Due to the complex nature of the leachate characteristics, neither conventional biological wastewater treatment nor chemical treatment processes separately achieve high removal efficiencies over the life of the landfill (Qasim and Chiang, 1994). The traditional methods of leachate treatment are biological, physical and chemical processes, often requiring a combination of these processes, or in a combined municipal wastewater treatment process (Qasim and Chiang, 1994; Tchobanoglous et al., 1993; U.S. EPA, 1995). The biological, physical and chemical treatment processes are summarized in Table 2-3.

Biological processes are either aerobic or anaerobic processes, and the main purpose is to reduce the biodegradable organic components to low concentrations (< 20 mg/L), at which point, nitrification and denitrification can be achieved. Biological processes are, generally, less expensive than chemical/physical processes (Ehrig and Stegmann, 1992). The biodegradability of landfill leachate can be monitored by evaluating the BOD_5/COD ratio. Generally, ratios are in the range of 0.5 or greater for new landfill leachate. Ratios in the range of 0.4 to 0.6 are taken as an indication that the organic matter in the leachate is readily biodegradable.

Table 2-3: Biological, Chemical, and Physical Processes and Operations Use for the Treatment of Landfill Leachate

Biological processes	Chemical Processes	Physical Operations
A. Aerobic	-Neutralization	-Equalization
1. Suspended growth	-Coagulation	-Screening
· Activated Sludge	-Precipitation	-Flocculation
· Nitrification	-Gas transfer	-Sedimentation
· Aerated lagoon	-Chemical oxidation	-Flotation
· Sequencing batch reactors(SBR)	-Chemical reduction	-Filtration
2. Attached growth	-Disinfection	-Air stripping
· Trickling filters	-Ion exchange	-Steam stripping
· Rotating biological	-Carbon adsorption	-Natural Evaporation
contactor(RBC)		
· Aerobic fluidized bed reactor	-chemically assisted	-Membrane processes
3. Combined suspended and	clarification(polymer	· Ultrafiltration
attached growth	only)	· Reverse osmosis
B. Anaerobic		· Electrodialysis
1. Suspended growth	-Wet air oxidation	
· Conventional		
· Anaerobic lagoons		
· Anaerobic sludge bed reactor (UASB)		
· Denitrification		
· Combined anoxic, anaerobic and		
aerobic system		
2. Attached growth		
· Anaerobic filter		
· Expanded bed or fluidized bed		
· Rotating biodisks		
· Denitrification		
3. Combined suspended and		
attached growth		
C. Aerobic-anaerobic stabilization ponds		

(Source: Qasim and Chiang, 1994; Tchobanoglous et al., 1993; U.S. EPA, 1995; Ehrig and Stegmann, 1992)

The BOD₅/COD ratio of the Trail Road Landfill leachate falls in the range of 0.42-0.53 as can be seen from Table 2-2, which would imply that the leachate is readily biodegradable. In mature landfills, the BOD₅/COD ratio is often in the range of 0.05 to 0.2. The ratio decreases because leachate from mature landfills typically contains humic

and fulvic acids, which are not as readily biodegradable (Tchobanoglous et al., 1993). However, biologically treated leachate still contains relatively high concentrations of COD and AOX that can be further reduced by other treatment methods (Ehrig and Stegmann, 1992). Innovative technologies for leachate treatment include ultraviolet radiation, gamma or electron beam radiation, surface modified clays, pervaporation, and electrochemical separation (U.S. EPA, 1995).

Over the last decade the concept of engineered bioreactor landfills has been developed for the management of landfill leachate. The fundamental principle used for waste treatment in a bioreactor landfill is leachate recirculation. Recirculation, or recycle, of leachate back to the landfill creates an environment favorable for rapid microbial decomposition of the biodegradable solid waste (Reinhart and Townsend, 1997). The moisture content of the waste is increased, the waste is shredded and nutrients can be added to the waste to enhance the rate of biodegradation of the organic matter and, hence, methane production (Warith, 2002). As a result, waste stabilization is accelerated and eventually causes a reduction in contaminant generation within the landfill, which ultimately decreases the cost of long-term monitoring. However, the implementation of bioreactor technology still faces many challenges, including regulator reluctance to approve such facilities, the availability of theoretical design criteria, the ability to uniformly wet the waste, and operator training issues (Reinhart and Townsend, 1997).

In recent years, both natural and engineered wetlands have been used to treat a variety of wastewaters, including agricultural wastewaters and runoff, mine drainage, secondary

wastewater effluent, storm water, as well as landfill leachate (Sartaj, 2001). Wetlands offer a wide spectrum of natural processes that may serve to reduce leachate contaminants. VOCs are air-stripped from the surface of the wetland waters and biodegraded by consortia of wetland microbes. Ammonium nitrogen may also volatilize, or undergo nitrification/denitrification. The wetland carbon cycle provides the energy source for nitrate reduction. Nutrients are seasonally utilized by wetland biota, and residuals accrete as new wetland sediments and soils. Metals are sequestered in tissues of growing plants, ion-exchanged onto wetland sediments, and precipitated as sulfides and oxyhydroxide co-precipitates (Kadlec, 1999). However, natural wetlands are considered natural resources and, thus, have to comply with the water quality requirements of regulatory agencies (U.S. EPA, 1987). In addition, the long-term effects of wastewater effluent disposal on peatlands are unknown. This practice could alter the structure or function of these natural ecosystems, which may be irreparably damaged. The use of natural peatlands should not become the focus of a compromise between the short-term goal of profitability, and the long-term priority of sustainable productivity. Therefore, researchers (Couillard, 1994) would only recommend the use of engineered peat systems for wastewater treatment, including landfill leachate, until the response of natural peatland ecosystems to effluent disposal has been fully assessed.

2.3 PEAT FILTER IN TREATMENT OF WASTEWATER

The use of peat for pollution control has received increasing attention over the past three decades. Many pollutants are adsorbed by peat under natural conditions resulting in lower concentrations of these elements in the ecosystem (Couillard, 1994). Peat is relatively

inexpensive (approximately 0.09 \$(US) per kg) in comparison to commercial ion exchange resins (4.40-22.00 \$(US) per kg) (Couillard, 1994). Besides being plentiful and relatively cheap, peat possesses several other characteristics that make it an attractive medium for wastewater treatment. Peat has proven to be an effective adsorbent (Nawar and Doma, 1989) and filtration medium (Toller and Flaim, 1988) for the purification of wastewaters, including septic tank effluent (Talbot et al., 1996; Viraraghavan and Ayyaswami, 1989; Rock et al., 1984) and landfill leachate (Lyons and Reidy, 1997; Heavey, 2003). In addition, peat has also been used in several waste handling applications, including cattle litter, horse, chicken, fox or mink, as a treatment system for the water purification plants or fish farms, as well as the wastes from composting processes (Selin and Nyrönen, 1985; Couillard, 1994).

2.3.1. PEAT CHARACTERISTICS

Peat is partially fossilized plant matter usually of a dark brown color that occurs in wet areas where there is a lack of oxygen and where accumulation of plant matter is more rapid than its decomposition (Viraraghavan and Ayyaswami, 1989). About 90% of Canada's 127 million hectares of wetlands are classified as peatlands, where peaty soils are predominant (Pries, 1994). The most important peat forming plants are *Sphagnum spp* (da Silva et al., 1993). Canada mainly produces sphagnum peat, which is used primarily for horticulture and agriculture (Bergeron, 1994). The composition of peat varies with location and depth, even within a given bog (Lyons and Reidy, 1997). Lüttig (1986) reported that peat composition varies with the parent material and with the environmental

conditions in which humification takes place: mineral content, pressure of overburden, physical transport, geothermal changes and microbial activity.

Several different systems are used for describing and classifying peat. Some of the most popular methods include the von Post system, the Radforth system and the American Society for Testing and Materials (ASTM) standard. The modified von Post method is widely used in Ontario for horticultural peat classification. In this system, the peat is classified by using the recognizable features of the original plant constituents that formed the peat. There are two principal types of peat: horticultural peat and fuel peat. Horticultural peat is characterized by low decomposition corresponding to a von Post value of H1-H5. It has a high fibre content, is light yellowish brown, and contains few colloidal residues. Fuel peat is highly decomposed with a von Post value of H6-H10. It is blackish in color and contains colloidal residues (Bergeron, 1994). Talbot et al. (1996) compared 21 types of peat in various states of decomposition and found that peats with humification levels of H2, H3 and H4 were best suited for use as a biofilter. The screening was based on leaching properties and the potential for clogging.

The main properties of peat are its high water holding capacity (Bergeron, 1994), low density (Buttler et al., 1994), large surface area ($>200 \text{ m}^2/\text{g}$) (McLellan and Rock, 1988), low heat conductivity, and high porosity (McLellan and Rock, 1988; Buttler et al., 1994; Mitsch and Gosselink, 1993), which make it an effective filter medium for the removal of contaminants. Bergeron (1994) reported that peat can hold up to twenty times its weight in liquids and gas. Correspondingly, bulk density varied from 0.04 g/cm^3 for

undecomposed Sphagnum peat moss to 0.261 g/cm^3 for well decomposed peat (Kinsley et al., 2003). Peat is a highly porous material with porosities in the range of 80-90% with values as high as 95 % (Kennedy and Van Geel, 2000). Williams and Crawford (1983) cited the work of Given and Dickinson (1975) stating that the pores in the peat often hold large amounts of static water leading to a high internal liquid hold-up within the peat matrix. This large retention time allows significant amounts of ion exchange, microbial activity and other reactions to within these areas (Williams and Crawford, 1983). The total porosity of peat decreases gradually with increasing decomposition, but is large for all peat materials (Boelter, 1969). In addition, microscopic studies have revealed that it is a highly porous material (Couillard, 1992). Boelter (1969) demonstrated that undecomposed peats contain many large pores which are easily drained at low suctions. Hydraulic characteristics of peats, such as moisture content and rate of water movement, depend largely upon the porosity and pore-size distribution of the material. These are in turn related to the particle-size distribution. As a consequence, the saturated hydraulic conductivity of peat can range by a factor of 5000 (Nichols and Boelter, 1982). A slightly decomposed fibric peat can have a saturated hydraulic conductivity as high as $3.9 \times 10^{-2} \text{ cm/s}$, whereas a highly decomposed sapric peat can be as low as $6.9 \times 10^{-6} \text{ cm/s}$ (Boelter, 1969). In leachate treatment, these physical characteristics are crucial because most of the dynamic interactions between the contaminants and the peat substrate will take place within the pore space of the material (Loxham, 1980).

Peats are largely organic materials with organic contents varying from 80 to 99 percent (Kinsley et al., 2003) and having relatively low ash contents of 0.5 to 2.5 percent

(Bergeron, 1994). The most studied and least understood soil organic components are soil humic substances, which consist of three major classes of chemicals, generally categorized as humic acids, fulvic acids, and humin. They are differentiated by their solubility in alkaline and acid solutions. Humic and fulvic acids are both soluble in alkaline solutions, but humic acids are precipitated in acid. Fulvic acid is soluble in both acidic and alkaline solutions. Humin is soluble in neither acidic nor basic solutions (Tate, 1987). Raw peat is fibrous and elastic with a pH of between 2.8 and 4.0 due to the presence of humic acids (Valentin, 1986). It is a rather complex material containing lignin and cellulose as major constituents. These constituents, especially lignin, contain polar functional groups, such as alcohols, aldehydes, ketones, acids, phenolic hydroxides, and ethers that can be involved in chemical bonding (Coupal and Lalacette, 1976; Viraraghavan and Ayyaswami, 1987; Dissanayake and Weerasooriya, 1981). The numbers and the types of oxygen-containing functional groups greatly influence the reactivities of humic substances (Hayes and swift, 1978). Undoubtedly the carboxyl and phenolic structures are the most important of these because they are the major groups responsible for the contribution by organic matter to the cation-exchange capacity (CEC) of peat, and they can have chelating effects (Schnitzer and Skinner, 1965). As a consequence, peat demonstrates a high cation exchange capacity and a low anion exchange capacity (Valentin, 1986). Peat is also reported to exhibit excellent ion exchange properties similar to those of natural zeolites (Sharma and Forster, 1993; McKay, 1996). The combination of the above mentioned properties, i.e. porous material, good adsorbent, capability of forming complexes with metals and having a capacity for ion exchange, makes peat an excellent filter medium for wastewater treatment.

As mentioned earlier, the properties of peat are affected by the environmental conditions that existed during its formation, the temperature, the pH and the degree of decomposition (Couillard, 1994). Also when peat is removed from its natural state, drained, dried and milled, significant changes occur in the properties of that peat. Some of these changes are loss of moisture holding capacity and changes in porosity and permeability (Couillard, 1994). Poots and McKay (1980) reported that the adsorptive capacity of peat could decrease with drying. They attributed this to a reduction in surface area from pore shrinkage during drying, as well as to the formation of cross-linkages between neighboring hydroxyl groups, due to the elimination of water. On the other hand, Sartaj (2001) reported that the most important sites for the adsorption of water onto organic matter are provided by carboxylic groups. Upon drying and exposure of polar sites, an internal pairing of OH and C=O may occur, as expressed by Equation 2-1 and 2-2. Internal pairing of functional groups produces stable sites, preventing peat and other organic matter to rehydrate upon wetting. This may be part of the reason for the irreversible behavior of organic matter upon wetting and drying (Tan, 1998). The above two statements of effect on drying are contradictory. However, Heavey (2003) demonstrated that the removal efficiency of a peat bed increased upon air drying, which supports the latter statement. In this research, Heavey (2003) demonstrated a treatment rate of 11.5 g BOD/m²/day and 3.4 g ammonia/m²/day in an unprocessed peat, compared to 36 g BOD/m²/day and 11 g ammonia/m²/day in an air-dried peat.

The cation exchange capacity of an organic soil should not be considered as the sum of the values of the CEC of the constituent components of the soil. The organic and mineral substances of soil mutually interact, thereby compensating for the mutual excess in charges. Humic substances such as peats coat the mineral particles, rendering their surfaces inaccessible to the cations in solution. In addition, Orlov (1992) noted the observations made by Aleksandrova that the formation of complexes and adsorption of cations by humic acid compounds, and iron and aluminium hydroxides lower the CEC. Iron and aluminium in heteropolar complex salts enter into the anionic part of the molecule and do not take part in exchange reactions. According to Aleksandrova, such salts are characterized schematically by the following generalized formula:

Where R is the humic acid residue, M is $\text{Fe}(\text{OH})_2^+$, $\text{Fe}(\text{OH})^{2+}$, $\text{Al}(\text{OH})_2^+$, $\text{Al}(\text{OH})^{2+}$, and M_1 are cations Ca^{2+} , Mg^{2+} , Na^+ , K^+ or Al^{3+} . During the cation exchange of such complexes, only the M_1 cations of the outer shell take part and a part of the carboxyl group is strongly blocked by M cations and they do not affect CEC. The capacity of such salts is 1.5 to 2 times less than that of pure humic acid.

In a peat system, a diverse microbial community is present (Lens et al., 1994). Some of these are individual and flocculated bacteria, rotifers, ciliates and fungal spores (Lens et al., 1994). These micro-organisms initially consume the dissolved organic carbon (DOC) (Coulson and Butterfield, 1978). Once the DOC is removed, the microorganisms will consume the organic matter of the peat itself causing the peat to disintegrate and organics to be leached out. If the wastewater loading rate is too low, there will be inadequate DOC and the treatment will be limited by the peat decomposition (Nichols and Boelter, 1982). Other micro-organisms that are present are *Nitrobacter* and *Nitrosomonas*, which are responsible for nitrification (Nichol and Boelter, 1982). The Microbial activity is a function of the availability of nutrients, the concentration of inhibitory compounds, physiochemical factors, or competitive interactions (Williams and Crawford, 1983).

Some disadvantages of using peat filter in wastewater treatment including STE and landfill leachate are: the yellowish color of the effluent; low chemical oxygen demand (COD) removals; and low effluent pH (Couillard, 1994). The yellowish color is due to leaching of fulvic acids from the peat matrix (Fuchsman, 1980). The COD which is removed by peat is counteracted by the addition of fulvic acids, causing initial net COD

removals to be low (Rana and Viraraghavan, 1987). Analysis revealed that color was higher in columns containing more peat, increased with increasing loading rate, and decreased with the total amount of wastewater passed (Bradeen, 1983). With time, the color diminishes and greater COD removals are attained because the amount of leachable fulvic acids decreases (Rock et al., 1984). In addition, the low pH is due to peat degradation, leaching of fulvic acids, and protons from the peat (Couillard, 1994; Fuchsman, 1980). In general, the acidity of soil solutions is caused by the presence of free organic acids or other organic compounds, containing acidic functional groups, free mineral acids (mainly carbonic acid), and other components showing acidic properties (Orlov, 1992). Of all the components showing acidic properties, Al^{3+} and Fe^{3+} ions have the maximum effect though their acidic property is comparable with the acidic properties of such acids as carbonic and acetic acids (Orlov, 1992). It is commonly believed that ion-exchange is the most prevalent mechanism for metal ion removal through a peat system. As mentioned earlier, the humification of peat produces humic and fulvic acids. Metals react with the carboxylic and phenolic acid groups of the acids to release proton. This is consistent with the principles of ion-exchange since, as more metal ions are adsorbed onto the peat, more hydrogen ions are released, thereby decreasing the pH (Brown et al., 2000). However, even with these problems the quality of the effluent satisfies the US EPA criteria for discharge into receiving waters (Couillard, 1994).

2.3.2. POLLUTANT REMOVAL IN PEAT

2.3.2.1 ORGANIC MATERIAL REMOVAL

The main removal mechanisms of organic matter within a peat filter are the physical filtration of solid particles containing organic matter and bacterial uptake (Kinsley et al., 2003). One of the most significant functions of the microbial component of the soil filter is the degradation of organic compounds (COD, BOD₅) contained in the applied wastewater. The main products of aerobic metabolism are CO₂, H₂O and new cells; while in the absence of oxygen, intermediate substances such as organic acids, alcohols, amines and mercaptans will accumulate (Miller, 1974).

2.3.2.1.1 BIOCHEMICAL OXYGEN DEMAND

The removal of carbonaceous organic matter in a peat system is mainly a biological one. However, Couillard (1994) reported that the organic compounds which are larger than the interstitial channels in peat are filtered out. Viraraghavan and Ayyaswami (1989) found in their 2-h batch studies that the peat can effectively adsorb 30-50% of dissolved BOD₅ (5-day biochemical oxygen demand) from septic tank effluent (STE), where the concentration of BOD₅ varied from 107-154mg/L. Hence, there are three mechanisms involved in BOD₅ removal: physical filtration of larger particle, adsorption of dissolved BOD₅, and biological degradation of organic matter by microorganism. The BOD₅ value is a measure of the amount of oxygen required by microorganism for the biodegradation of organic matter. When favorable conditions for heterotrophic bacteria are maintained, organic carbon is consumed, thereby effecting a reduction in BOD₅.

Heavey (2003) reported almost 100% removal of BOD₅ in the treatment of landfill leachate using an air-dried peat bed at a hydraulic loading rate of 60 mm/day. Talbot et al. (1996) monitored 4 commercial peat biofilters over a two-year period and found an average BOD₅ removal rate of 97%, from 191 mg/L to 6 mg/L. Reductions in BOD₅ resulting from peat filtration have been reported to be greater than 90% in some studies (Brooks et al., 1984; Rock et al., 1984), yet less (61% to 81%) in others (Lyons and Reidy, 1997; Viraraghavan and Kikkeri, 1988). However, McLellan and Rock (1986) reported that Stanlick indicated that this parameter can be improved simply with the use of a sand filter.

2.3.2.1.2 CHEMICAL OXYGEN DEMAND

The chemical oxygen demand (COD) data of peat systems is difficult to interpret in terms of overall removal because there is a COD contribution to the effluent by the peat itself (Couillard, 1994; Viraraghavan and Ayyaswami, 1989; Rock et al., 1984). Humic and fulvic acids, resulting from the chemical breakdown of peat, are often leached from the peat and contribute to the effluent COD.

In column studies using STE, slaughterhouse wastewater, dairy wastewater, and landfill leachate as a source of COD, removal efficiencies were reported on the order of 80 % (Rock et al., 1984), 51-65% (Viraraghavan and Kikkeri, 1988) and 84% (Lyons and Reidy, 1997) for hydraulic loadings of 8.1 cm/d, 213 cm/d-355 cm/d and 17 cm/d, respectively. These results could be a function of loading rate, where smaller loading rates led to greater removal efficiencies due to a longer residence time provided for

biodegradation. Field experiments demonstrated COD removal efficiencies > 80% (Brooks et al., 1984), 78% (Talbot et al., 1996), and 95% (Riznyk et al., 1993) for hydraulic loading rates of 1.5 cm/d–4.1 cm/d, 7 cm/d–25.8 cm/d and 2.12 cm/d, respectively. The efficiency of field studies is higher in comparison to column studies, where lower hydraulic loading rates led to more efficient COD removals.

Batch kinetic studies by Viraraghavan and Ayyaswami (1989) showed that peat was effective at adsorbing 35%-50% of dissolved COD. It was also found that COD increased with the amount of peat added because of the contribution of organic chemical load by peat itself. However, column experiments conducted by Rock et al. (1984) showed that improved COD removal was achieved after the initial leaching of COD from peat had stopped.

2.3.2.2 NITROGEN REMOVAL

The removal of the nitrogenous pollutants of landfill leachate by peat systems is of great interest because of their potentially adverse effects on receiving water, as well as the health risks associated with nitrates. Concerns related to the presence of nitrogenous wastes include dissolved oxygen (O_2) depletion, toxicity, eutrophication, and methemoglobinemia (Gerardi, 2002). Therefore, the reduction of nitrogen compounds in wastewater is an inevitable preoccupation for the modern society (Couillard, 1994).

2.3.2.2.1 AMMONIA-N REMOVAL

The term total ammonia-nitrogen represents the sum of the $\text{NH}_3\text{-N}$ (ammonia form of nitrogen) and $\text{NH}_4^+\text{-N}$ (ammonium ion form of nitrogen). The relative quantities of $\text{NH}_4^+\text{-N}$ and $\text{NH}_3\text{-N}$ are dependent on the pH and temperature of the wastewater. In the temperature range of 10°C to 20°C and pH range of 7 to 8.5, about 95% of the reduced form of nitrogen is present as $\text{NH}_4^+\text{-N}$ (Gerardi, 2002). Generally, ammonia-nitrogen removal in leachate can be attributed to (i) volatilization of $\text{NH}_3\text{-N}$; (ii) adsorption of $\text{NH}_4^+\text{-N}$, (iii) nitrification; and (iv) biological uptake (Couillard, 1994). However, Heavey (2003) stated that the treatment process for ammonia is temporary storage by cation exchange, followed by the release of NH_4^+ from the attachment sites, followed by nitrification.

It is unlikely that the volatilization of $\text{NH}_3\text{-N}$ would occur at low pH levels, as the soluble $\text{NH}_4^+\text{-N}$ would be expected to dominate. However, adsorption of $\text{NH}_4^+\text{-N}$ by organic matter is likely due to its high cation exchange property. Heavey (2003) investigated the removal efficiency of peat in the treatment of leachate both in laboratory-scale and full-scale systems over a 4-year period, and reported that the main mechanism of ammonia-N removal in peat was nitrification rather than its adsorption capacity of NH_4^+ due to its CEC. In addition, Aspinwall (1995) concluded from his research that peat treatment of ammonia in landfill leachate would be limited by the CEC of the peat, and finally demonstrated that the peat used as little as 6% of the available cation exchange capacity in ammonia-N removal. Heavey (2003) also reported that the peat column used less than 4% of its CEC in the treatment of ammonia-N. However, the CEC of soil depends on

particle size distribution, as well as the degree of humification. The variation of CEC with pH is very noticeable for humic materials like peat. In neutral and acidic media, only the hydrogen of the carboxyl groups take part in exchange reactions, while in alkaline media, phenolic and other hydroxyl groups get dissociated, thereby increasing the CEC considerably (Orlov, 1992).

McNevin et al. (1999) studied the adsorption of ammonia onto peat. They found an initially high removal rate due to adsorption, followed by a slower rate of biological nitrification. The study, treating 200mg/L of NH_4^+ -N, reported ammonium degradation rates of 0.46 mg/L.h with 0 ppm alkalinity to 1.3 mg/L.h with 1000 ppm alkalinity. The peat removed 66% of the ammonia. Biological nitrification is the conversion or oxidation of ammonium ions to nitrite ions, and then to nitrate ions. During the oxidation of ammonium and nitrite ions, oxygen is added to the nitrogen ion by a unique group of organisms, nitrifying bacteria.

The rate of nitrification can be affected by a number of factors, which will impact directly on the design and operational characteristics of the nitrification process. The maximum specific growth rate of nitrifiers (i.e., about 0.3-1.2/day) is considered to be 10-20 times slower than that of heterotrophic bacteria, which are responsible for the stabilization of

organic matter. The optimal pH for nitrification is in the range of 7 to 8.5, but nitrification can take place in a pH range of 6-10. In addition, temperature significantly affects the growth rate of nitrifiers. Nitrification occurs over a range of about 4-45°C, with an optimum temperature range of about 30-35°C. In the range of 5-30°C, the nitrification reaction rate will double with each 7°C increment in temperature (Environment Canada, 2003). Heavey (2003) demonstrated that NH_4^+ -N removal increased during the summer months from 62 to 94% due to an increase the leachate temperature from 7.8°C to 17.3°C, respectively. In addition, higher rates of ammonia removal ($>11\text{g/m}^2/\text{day}$) can be achieved by using dried peat (Heavey, 2003). However, oxygen must be available for nitrification to occur, as indicated in Equation 2-4, which is in turn related to the physical properties of peat, as well as the depth and hydraulic loading rate of the peat filter. Brooks et al. (1984) demonstrated that a number of fungi can use organic-N, ammonia-N compounds and NO_3^- -N directly. The reduction in N components may be due, in part, to the activity of these fungi (Brooks and Zibilske, 1983). However, their contribution is usually significant only under low-pH conditions. At times, their growth can be so rapid that the filter clogs and ventilation becomes restricted (Tchobanoglous and Burton, 1991).

2.3.2.2.2 NITRATE-N REMOVAL

In the case of nitrate-N removal, adsorption of NO_3^- -N is not plausible since peat demonstrates a low anion exchange capacity (Valentin, 1986). However, denitrification can reduce the NO_3^- -N concentration in an anaerobic environment within the peat filter. Denitrification results in the biological transformation of nitrate into nitrogen gas via

nitrite (NO_2^-) and nitrous oxide (N_2O). The optimal pH for denitrification is in the range of 6.5-7.5 and the impact of temperature is similar to that discussed for heterotrophic aerobic bacteria (Environment Canada, 2003). Couillard (1994) stated that peat filter beds are ideal areas for denitrification because their substrates contain large amounts of organic carbon, the lower part of the bed is often anaerobic, and because both $\text{NH}_4^+\text{-N}$ and organic-N entering or originating from the peat can be converted to $\text{NO}_3^-\text{-N}$.

Laboratory studies by Rock et al. (1984) demonstrated that the major mechanism in the removal of nitrogen was denitrification. In this research, significant denitrification was found to occur under anaerobic conditions where 62% of total-N removal was observed in a 30 cm peat column compacted to a density of 0.12 Mg/m^3 . Moreover, Lyons and Reidy (1997) reported an 84% reduction of $\text{NO}_3^-\text{-N}$ in a 2 m column, while Heavey (2003) and Talbot et al. (1996) reported increases in $\text{NO}_3^-\text{-N}$ due to nitrification under aerobic condition where column heights were 1 m in both studies. The above results were contradictory in terms of anaerobic zone formation with respect to column height, which might therefore suggest that the column height is not the important parameter responsible for denitrification. The formation of anaerobic zones may be a function of column compactions and hydraulic loading rates which are the important factors to be considered for nitrification and denitrification processes. Thus, both aerobic and anaerobic environments are required within the peat if nitrification and denitrification are desired for the removal of ammonia-N and nitrate-N. Both could take place in the same peat filter profile by alternating flooding and drying periods (Couillard, 1994).

2.3.2.3 TOTAL SUSPENDED SOLID REMOVAL

Physical filtration is the main removal mechanism responsible for the reduction of total suspended solid (TSS) in a peat filter. Peat has a highly porous nature, which provides for the excellent filtration of solid particles. Zhou et al. (2003) reported that the TSS removal efficiency of peat filters was promising when treating highway runoff. Talbot et al. (1996) described a 92% reduction, from 58mg/L to 4mg/L, of TSS from residential effluents applied to four peat filter system over a two-year period.

Laboratory column studies by Rock et al. (1984) demonstrated excellent suspended solid removal efficiencies of 94%, where the influent TSS was 73mg/L and operated for 420 days. In a 26-day column study conducted by Lyons and Reidy (1997) leachate was applied at a hydraulic loading rate of 17 cm/day. In this study, TSS concentrations were reduced by 75% from 3190 mg/L to 810mg/L. Viraraghavan and Kikkeri (1988) used peat columns to remove suspended solids from slaughter house and dairy wastewaters. During a 5-day period, 94% of the suspended solids were removed from the slaughterhouse wastewater, at a filtration rate of 3.55 m³/day-m² and TSS concentration of 243 mg/L. In the dairy wastewater, 99% of the suspended solids were removed at the end of an 81-h period, at a filtration rate of 2.13 m³/day-m² and suspended solids concentration of 2650 mg/L.

McLellan and Rock (1988) conducted a column study to evaluate peat as a pre-treatment medium for landfill leachate. Applying municipal landfill leachate at 4.1 cm/day, it was found that a densely packed column of air-dried peat (180 kg/m³) clogged in 90 days,

whereas a column packed at a density of 120 kg/m^3 had not clogged after 193 days of operation. The clogging observed in the densely packed column was attributed to the suspended solids loading of 165 mg/L in combination with biomass growth filling in the void spaces. Therefore, the above review suggested that the clogging of peat column is a function of TSS concentration, where lower TSS concentration can result in a longer period of operation, as well as peat density.

2.3.2.4 HYDROGEN SULFIDE REMOVAL

Hydrogen sulfide (H_2S) is one of the malodorous compounds most widely emitted from wastewater as well as landfill leachate. Its odor can be detected at levels as low as 0.02 ppm , headaches and nausea symptoms are exhibited at about 10 ppm , at death occurs at 100 ppm (Rayner-Canham, 1996). A concentration of a few tenths of a milligram of H_2S per liter in drinking water causes noticeably disagreeable odors and tastes (Dalai et al., 1999). H_2S is soluble in water and can be transported considerable distances before being released. H_2S is produced naturally by anaerobic bacteria, which decompose organic matter containing sulfates (SO_4^-). Dissolved sulfide may be present in forms of $\text{H}_2\text{S}_{(\text{aq})}$, HS^- , or S^{2-} depending on the pH of the water. For low pH levels of less than 5, the predominant species is $\text{H}_2\text{S}_{(\text{aq})}$. For $\text{pH} > 9$, S^{2-} and HS^- ions are predominant. At low pH values, $\text{H}_2\text{S}_{(\text{g})}$ will be lost into the atmosphere due to the $\text{H}_2\text{S}_{(\text{aq})} - \text{H}_2\text{S}_{(\text{g})}$ equilibrium, causing odor problems (Peters and Ku, 1987).

The mechanisms of sulfide reduction are likely chemical and biological oxidation in the aerobic environment of a peat filter, as opposed to chemical adsorption to the peat

(McNevin et al., 1999). Wada et al. (1986) reported that after acclimation of the peat filter, a facultative autotrophic bacterium, *Thiobacillus intermedius*, was primarily responsible for H₂S oxidation. In this studies, when pH was maintained at 3, constant removal of H₂S as 1.4×10^{-13} g- H₂S-S/h/cell continued without a decline in the cell number of bacteria. Peat has been shown to be an effective filter for H₂S_(g). Brennan et al. (1994) studied the use of peat biofilters to reduce H₂S_(g) and found removal rates of >99% with influent concentrations of up to 60 ppm.

2.3.2.5 BORON REMOVAL

Boron is one of the most troublesome trace elements in soil management. It is a non-metal element with the only known valence states of 0 and +3. It does not occur as a free element in the environment, but it is usually found combined with oxygen to form borates and borosilicates (Sartaj, 2001). There is not much information available regarding the adsorption of boron by peat filter; however, adsorption of boron by humic material has been investigated by a few researchers (Gu and Lowe, 1990; Baohua and Lowe, 1990).

The most important factor affecting the adsorption of boron is pH, where increasing pH enhances boron adsorption. Baohua and Lowe (1990) reported that boron adsorption by humic acid is pH dependent showing a peak at pH of 9. At acidic pH levels, boron is mainly present as molecular boric acid. Since it does not carry a charge and soil affinity for this specie is low, therefore, the amount of adsorption is small. As the pH increases, B(OH)₄⁻ concentration increases which results in higher adsorption. At pH levels above 9-10, high concentrations of OH⁻ ions results in a decrease in adsorption due to

competition effect for adsorption sites (Gupta et al., 1985). Sartaj and Fernandes (1998) performed column studies for the treatment of landfill leachate and found 90% removal of boron from an average of 15.0 mg/L to 1.34 mg/L in a peat filter with a depth 1.4 m.

2.3.2.6 BARIUM REMOVAL

Barium (Ba) is a toxic metal element in the periodic table that is chemically similar to calcium, yet is soft and, in its pure form, is silvery white resembling lead. It is an alkaline earth metal, which oxidizes readily when exposed to air. Barium is highly reactive with water and alcohol and can be decomposed by water or alcohol. Vary little research has been undertaken which specifically addresses barium removal in peat system. However, considerable research has been undertaken regarding metal removal using peat and peat filters.

Peat is a polar material and it is able to adsorb large quantities of most metals, and is thus competitive with other natural adsorbents (Couillard, 1992). Metals are removed principally by two mechanisms: ion exchange and the formation of complexes, including chelation (Couillard, 1994). Crist et al. (1996) concluded that metal ions react with the carboxylic and phenolic acid groups of the humic and fulvic acids in peat to exchange with protons or, at sufficiently high pH, with the anionic sites to displace existing metals. Couillard (1994) stated that di- and tri-valent ions are chelated by bond formation with aromatic carboxylate hydroxyl groups present in humic acids. In addition to being excellent chelating agents, humic acids are capable of retaining large quantities of metals

by cation exchange and surface adsorption. The nature of the impurities present in the peat material also influences its cation exchange capacity.

Cations are selectively adsorbed by peat, Pakarinen et al. (1981) reported the following order of affinity: $\text{Pb}^{2+} > \text{Cu}^{2+} > \text{Zn}^{2+} > \text{Mn}^{2+}$, and Maslennikov and Kiseleva (1989) reported a similar order of metallic cation exchange ($\text{Cu}^{2+} > \text{Zn}^{2+} > \text{Fe}^{3+} > \text{Ca}^{2+}$). However, with granulated peat, the following order $\text{Fe}^{3+} > \text{Cu}^{2+} > \text{Cr}^{3+} > \text{Zn}^{2+} > \text{Ni}^{2+}$ was reported (Chistova et al., 1990). As mentioned earlier, the CEC of peat and organic soils depends on the particle size distribution as well as the degree of humification. The variation of CEC with pH is very noticeable for humic materials like peat. In neutral and acidic media, only the hydrogen of the carboxyl groups takes part in reactions. In alkaline media, phenolic and some other hydroxyl groups are dissociated, thereby increasing the CEC considerably (Orlov, 1992). Cameron (1978) performed column studies for the treatment of landfill leachate with peat and found better metal removal capacities at pH 8.4, than at pH 4.8. They noted that this could be attributed to the precipitation of metal complexes at the higher pH rather than to adsorption. Cameron (1978) concluded that raising the pH to near neutral would likely increase the adsorption capacity of peat, which contradicted findings by Orlov (1992) for neutral pH and need to be confirmed through further investigations.

Brown et al. (2000) reported that peat can effectively remove many metal species from wastewater including: Hg, Cd, Zn, Pb, Cu, Fe, Ni, Cr (VI), Cr (III), Ag and Sb. A column study was conducted by Malterer et al. (1989) which investigated the removal of Cd and

Ba by peat. Three types of peat were investigated; an acidic (pH 3.2) Sphagnum peat moss, a slightly acid (pH 5.4) reed-sedge peat, and a slightly alkaline (pH 7.5) reed-sedge peat. Chromium was removed by all 3 types of peat with the acid Sphagnum moss performing the best, reducing Cr from 1-2.7 mg/L to <0.1 mg/L. The peat initially precipitated and immobilized Ba, mostly as barium sulfate, but slowly released barium over time.

2.4 SUMMARY

Landfill leachate is initially a high-strength wastewater, characterized by high organic matter (COD, BOD₅) and ammonia concentrations, and by the presence of potentially hazardous compounds such as heavy metal. Therefore, the treatment of landfill leachate via conventional wastewater treatment systems often present unique problems in terms of meeting effluents discharge limits because of its high contaminant strength and large variation over the life span of the landfill.

In recent years, peat has been identified as an alternative low-cost filter medium for the treatment of landfill leachate because of its high porosity (80-90%), high water holding capacity, high adsorption capacity, low density, large surface area (>200 m²/g), excellent ion exchange properties. Peat filter systems have been shown to be effective in the removal of COD, BOD₅, ammonia-N, nitrate-N, H₂S, TSS, boron, as well as barium.

The removal efficiencies and the total operational life of peat filter systems might be greatly influenced by the highly organic matter, ammonia, and TSS concentrations, while

involved in treatment of landfill leachate. Thus, this research focused on the removal performance and the operational life expectancy of a peat biofilter system preceded by an aeration chamber with an attached growth media under different contaminant and hydraulic loading rates and continuous flow condition.

CHAPTER 3

METHODOLOGY

3.1 EXPERIMENTAL DESIGN

From the studies presented in the previous chapter, it can be concluded that the contaminant removal performance and the total operational life of the peat biofilter system are very important in terms of organic (COD, BOD₅), ammonia-N, and TSS constituent loading, as well as hydraulic loading rate (HLR). Therefore, in this research, the performance and operational life expectancy of peat biofilter preceded by an aeration chamber with a support media for an attached biofilm were investigated with particular emphasis on different hydraulic and contaminants loading rates under continuous flow conditions. The attached growth medium, which has a large active surface area and texture promoting the rapid growth of a biofilm, could reduce the contaminant load, especially ammonia-N and BOD₅, on the peat filter, and as a consequence, may significantly increase the operational life of the peat biofilter system. The aeration chamber was operated at a constant air flow rate of 3.40 m³/day and HRTs of 5 and 2 days in this study. Simultaneously, the aerated leachate was introduced at two different hydraulic loading rates: 8.28 cm³/cm²/day and 10.82 cm³/cm²/day. Each loading rate was supplied to respective sets of triplicate peat columns in both HRTs of this study as summarized in Table 3-1.

Table 3-1: Two Phase of the Project

Project Phase	Aeration Basin	Peat Columns
5-day HRT	HRT= 5 days, and Air flow=3.40 m ³ /day	HLR= Average 8.28 cm ³ /cm ² /day for first set of triplicate columns, and average 10.82 cm ³ /cm ² /day for second set of triplicate columns.
2-day HRT	HRT= 2 days, and Air flow=3.40 m ³ /day	HLR= Average 8.28 cm ³ /cm ² /day for first set of triplicate columns, and average 10.82 cm ³ /cm ² /day for second set of triplicate columns.

Laboratory investigations were conducted using the bench-scale experimental set-up illustrated in Figure 3-1. Masterflex® TYGON tubing was used to connect each of the stages: from the raw leachate container to the aeration basin, from the aeration basin to the peat column inlet, and from the distilled water container to the control peat column inlet. There were also two calibrated Masterflex® peristaltic pumps, each attached with a single pump head, employed to maintain constant flows from the raw leachate to the aeration basin, and from the distilled water container to the control peat column. Two sets of pumps were engaged to feed the two sets of triplicate peat columns with aerated leachate from the aeration basin. Each set of these pumps was assembled with three Masterflex® Easy-Load® pump heads attached to a Masterflex® peristaltic pump to attain a constant flow rate for same rpm (revolutions per minute). All four pumps were attached to a GRASSLIN (model CP-924) timer which was set to intermittently turn all pumps on five times a day, for a total of ten minutes per day in this continuous system set-up.

The raw leachate was collected every bi-monthly from the City of Ottawa Trail Road landfill in a set of plastic containers and stored in the refrigerators at 4° C. Each of the containers (28cm X 23cm X 40cm) had a capacity of 20 L. The raw leachate was passed to a cylindrical aeration tank (64 cm X 44 cm ID) by a peristaltic pump at a flow rate 4.5 L/day, which was equal to the sum of the influent rates of the peat filters. An air pump, MAP2X Maxair 2XL, was utilized to inject air into the leachate at an air flow rate of 3.40 m³/day. To attain an effective aeration a 28 cm long perforated hose with a 1 cm outside diameter, was placed in a spiral shape on the base of the aeration tank. In addition, a spun plastic attached growth media was used in the aeration basin in order to get a better performance of the aeration basin by providing a support media for biofilm growth. The digital pictures of this research work are presented in the Appendix C.

The aerated leachate was then fed to two sets of triplicate peat columns from the aeration basin by two sets of peristaltic pumps. Each of the triplicate columns was fed at a total average 8.28 cm³/cm²/day and 10.82 cm³/cm²/day, respectively. Samples of the raw leachate, aerated leachate and column effluents were collected and analyzed in order to assess the performance of the aeration basin with biofilm growth for contaminant removal at different HRTs, 5 and 2 days, as well as the removal efficiencies and life expectancies of the peat biofilters. A blank column was operated with distilled water in the same manner as the higher HLR at an average 10.82 cm³/cm²/day to observe the potential leaching of constituents from the peat and the behavior of the peat filter under control conditions.

3.2 PROPERTIES OF PEAT

Sphagnum peat was used in this research, and the peat was obtained from a commercial peat extraction operation in Alfred, Ontario. The peat was very moist, black in color, and had a medium level of decomposition (von Post level H4-H5). Peat from the same source was employed in a previous study by Kinsley et al. (2003) and was characterized in their study. They reported values for moisture content (%), bulk and dry density (%), volatile solids (%), pH, CEC (cmol+/kg), organic and inorganic C (%), Total N (%), Total S (%), acid detergent fibre (%), neutral detergent fibre (%), and lignin content (%) of the peat. As such, the peat material used in this study was not characterized again for these parameters. However, as there is a possibility that these parameters could change during air-drying, a few tests were performed for comparison. The peat material contained a few larger twigs and clumps of clay, which were removed by hand before conducting the following experiments.

3.2.1 PARTICLE SIZE DISTRIBUTION

Before packing the column with peat, the particle size distribution of the sample was determined according to ASTM Standard (D2977-71). In this experiment, two different sieve sizes, No. 8 and No. 16, were used to determine the percentage of coarse (fraction retained on No. 8 mesh), medium (fraction retained on No. 16 mesh) and fine (fraction passing through No. 16 mesh) particles rather than using No. 8 and No. 20. The mesh No. 16, which has an opening of 1.18 mm, was used in order to elevate the scale between fine and medium particle size from No. 20 (0.85 mm). First, the entire peat sample was sieved with No. 8, and the fraction retained and pass through 8-mesh were collected into two

separate buckets. The fraction passed through No. 8 was then sieved with No. 16, and the fractions retained and passed through 16-mesh were collected in two separate buckets. Finally, the three different fractions were weighed and mixed uniformly prior to packing the columns. The same peat was used for both HRTs 5-day & 2-day; therefore, the particle size distribution in the peat columns was assumed to be the same for both experimental studies.

3.2.2 MOISTURE CONTENT

The moisture content was determined for the peat material used in packing the columns for both the 5-day and 2-day HRTs. The test was conducted according to ASTM Standards (D 2974-87). Triplicate samples were used in this experiment. The moisture content was determined by drying the peat samples at 105° C for 24 hours. After a 2-hour cooling period in a desiccator, the moisture content was calculated according to the following equation on an as received mass basis.

$$\text{Moisture Content (\%)} = \frac{A - B}{A} 100\% \quad (3-1)$$

Where, A is the as received mass of the peat specimen (g) and B is the sample mass remaining after drying at 105° C.

3.2.3 ASH AND ORGANIC MATTER CONTENT

The ash and organic matter content were determined for the peat samples used in this research. In this experiment, the triplicate peat specimens from moisture determination were ignited in muffle furnace at 440° C according to ASTM Standards (D 2974-87). The temperature was gradually brought to a temperature of 440° C and the samples were ignited for a 2-hour period and then allowed to cool for another 2 hours in a desiccator. The specimens were then weighed. The mass remaining after ignition was the ash content and included mineral impurities such as sand.

$$\text{Ash Content (\%)} = \frac{C}{B} 100\% \quad (3-2)$$

The organic matter content is the fraction of material that has been ignited and volatilized.

$$\text{Organic Matter (\%)} = 100.0 - \text{Ash Content, (\%)} \quad (3-3)$$

Both values were reported on an oven-dried mass basis; where C is the mass of ashes remaining after ignition (g).

3.2.4 BULK DENSITY

The bulk density of the peat in the columns for both the 5-day and 2-day HRTs was determined according to the ASTM Standard (D4531-86). After the particle size

distribution determination, the peat was uniformly mixed in a large container by hand. Each of the seven columns as shown in Figure 3-2 was weighed empty and then packed with the peat according to the procedure described in Section 3.3.1.2.1 for the 5-day and 2-day HRTs. In the 5-day HRT study, the emphasis was given to compact the peat into the column up to the total desired height, but equal weights of peat were used in the 2-day HRT. Each of the compacted peat columns was then weighed and the bulk density was calculated according to the following equation:

$$\text{Bulk Density (kg/m}^3\text{), } \rho = \frac{M}{AL} \quad (3-4)$$

Where the bulk density is expressed on an air dried mass basis, M is the mass of the air-dried peat (kg), A is the cross-sectional area of the column (m²) and L is the peat depth in the column (m).

3.2.5 HYDRAULIC CONDUCTIVITY

The hydraulic conductivity of the compacted peat columns was determined using a modified version of the ASTM Standard Method (D 4511-92). The previously prepared columns were flooded for a period of 24 hours, using a constant head set up, for which the flow into each column equaled the flow out. For a constant hydraulic head differential of 51.5 cm across the peat column, water samples were collected at 1-minute intervals in

a pre-weighted set of plastic bottles. The weight of water collected was determined and, assuming 1 g of water is equal to 1 cm³ of water, and the volume of water was computed. Next the cumulative volume of water collected was plotted against time and the flow rate was calculated from the straight portion of the curve. The hydraulic conductivity was then computed according to Equation 3-5.

$$k \text{ (cm/s)} = \frac{L}{a(\Delta H)} Q \quad (3-5)$$

Where k is the hydraulic conductivity in cm/s, Q is the sustained flow rate (cm³/s) and ΔH is the constant hydraulic head differential applied to maintain a corresponding sustained flow rate (cm). This procedure was repeated for constant hydraulic head differentials of 32 cm and 62 cm, and the average hydraulic conductivity was reported. Hydraulic conductivity values are typically corrected from the experimental tap water temperature to a reference of 20° C. Therefore, the temperature correction was calculated for each of the columns according to the Equation 3-6. The same procedure was followed for all the columns in this study.

$$k_{20} = k_T \left(\frac{\mu_T}{\mu_{20}} \right) \quad (3-6)$$

Where, k_{20} is the hydraulic conductivity at 20° C, whereas k_T is the hydraulic conductivity at T°C. μ_T is viscosity of water at T°C, and μ_{20} is viscosity of water at 20°C.

3.3 COLUMN EXPERIMENTS

3.3.1 EXPERIMENTAL SETUP

As previously mentioned, the experimental setup for this study consisted of an aeration tank supplied with a biofilm growth media, which was operated for HRTs of 5 and 2 days during two different phases, and two sets of triplicate peat columns, which were fed at average hydraulic loading rates of 8.28 cm³/cm²/day and 10.82 cm³/cm²/day, respectively, during both HRTs. The performance and life expectancy of the peat biofilters, as well as the contaminant removal efficiency of the aeration tank, were evaluated using a bench-scale laboratory set-up.

3.3.1.1 AERATION BASIN

3.3.1.1.1 HYDRAULIC RETENTION TIME

For the purpose of this experiment, the hydraulic retention time (HRT) refers to the amount of time in days for leachate to pass through the volume of the aeration tank. Changes in HRT through the aeration tank would affect the biological activity within the biofilm established on the growth media. For example, decreasing HRT could adversely affect nitrification, while increasing HRT would favor nitrification and the solubilization of colloidal BOD (i.e. proteins, lipids) and particulate BOD (i.e. cellulose) (Gerardi, 2002). The HRT of the aeration tank was expressed as follows:

$$HRT(day) = \frac{V}{Q} \quad (3-7)$$

Where V is volume of aeration tank (L) and Q is the flow rate (L/hours). In this study, the HRT of the leachate in the aeration tank was 5 days and 2 days.

3.3.1.1.2 AIR FLOW RATE

A diffused aeration technique was used to provide continuous aeration to the raw leachate in the aeration basin for both the 5-day HRT and 2-day HRT. The air was injected under pressure by a MAP2X Maxair 2XL air pump (120 watt, 142.72 m³/day, 41.37 kPa) at a constant air flow rate of 3.40 m³/day through a 28 cm long and 1 cm outside diameter perforated hose, which was placed in a spiral shape at the base of the aeration tank. A flow meter was installed to maintain a constant air flow rate by the air pump throughout the experiment.

The layout of diffusers in a basin has an important influence on the performance of the system. Basin geometry, diffuser type, diffuser submergence, diffuser density and placement of the diffusers should all be considered in the effective design of the system (Mueller et al., 2002). However, these parameters were not considered in the design of the diffuser, as this was considered to be beyond the scope of this research.

3.3.1.1.3 BASIN GEOMETRY

A cylindrical tank of 44 cm diameter and 64 cm depth was used as an aeration basin. However, the effective volume of the aeration basin was calculated based on the HRT, 5 days and 2 days, and the corresponding flow rate according to the Equation 3-7. As such,

the effective volumes of the aeration tank were 22.50 L and 9.00 L for the HRTs of 5 days and 2 days, respectively.

3.3.1.1.4 FLOW RATE

The required inflow rate was determined based on the total outflow rate. The total outflow rate was equal to the sum of the hydraulic loading rate of the peat columns, $8.28 \text{ cm}^3/\text{cm}^2/\text{day}$ and $10.82 \text{ cm}^3/\text{cm}^2/\text{day}$, for each of the two sets of triplicate columns. Thus, the total required inflow to the aeration basin was 4.5 L/day (i.e. $3 \times 8.28 \text{ cm}^3/\text{cm}^2/\text{day} \times (\pi(10)^2/4) \text{ cm}^2 + 3 \times 10.82 \text{ cm}^3/\text{cm}^2/\text{day} \times (\pi(10)^2/4) \text{ cm}^2$) for both HRTs 5 and 2 days.

3.3.1.1.5 ATTACHED GROWTH MEDIA

Aerobic attached-growth biological treatment processes are generally used to enhance the removal of organics from wastewater, and enhance nitrification. The most common attached-growth processes include the trickling filter, the roughing filter, rotating biological contactor, and fixed-film nitrification reactor. In this study 5 kg of a novel, commercially available, spun plastic attached growth media, as shown in Figure C-3 in the Appendix C, was used in the aeration basin in order to allow for the biodegradation of organics and provide a nitrifying environment for the treatment of the leachate. This would then increase the life expectancy of the peat biofilter by increasing the length of operational time before clogging conditions in the biofilter would be reached in both the 5-day and 2-day HRTs. The same attached growth media has been effectively used in the BIONEST bioreactor for the treatment of septic tank effluent (Bionest Tech. Inc., 2004; Environment Canada, 2004). Bionest Tech. Inc. (2004) reported that the attached growth

media has a very large active surface area and texture promoting rapid growth of micro-organisms.

3.3.1.2 PEAT COLUMNS

3.3.1.2.1 COLUMN DIMENSION

Columns, made of acrylic plastic tubes, 10 cm inside diameter and 25 cm long, were used in this study. A schematic diagram of an individual column is shown in Figure 3-2. Prior to packing, a particle size analysis of the peat material was conducted with two different sieve sizes, No. 8 and 16, as discussed in Section 3.2.1. Each column was packed in same manner. Before packing the column with the peat material, 1 cm of fine washed sand was placed on top of a geotextile filter to prevent the peat from clogging the drainage area. Each of the peat columns was compacted in 3 layers using a 1.4 kg weight with the same outer diameter as the inside diameter of the column. The weight was fallen from a 3 inch height with a total 6 blows for each layer. The same procedure was repeated for each layer to achieve a fairly uniform compaction throughout the depth of the peat column.

3.3.1.2.2 HYDRAULIC LOADING RATE

The hydraulic loading rate is one of the most important operational parameter affecting the rate of clogging and treatment efficiency of peat biofilters. As previously mentioned, peat moss is porous and has a relatively high hydraulic conductivity, which also depends upon the peat's degree of decomposition (Couillard, 1994). Hydraulic conductivities as high as 140 cm/hr have been reported (Boelter, 1969). However, even under light, sustained loads, peat will undergo significant volume changes which will influence

(decrease) the hydraulic conductivity of the deposit by several orders of magnitude (ASTM Standard, D4511-92).

Rock et al. (1984) suggested a hydraulic loading of $< 8.1 \text{ cm/day}$ for treating septic tank effluent. While, Talbot et al. (1996) investigated a prototype peat biofilter performance for a hydraulic loading rate of 13 cm/day ($13 \text{ l/m}^2\text{-d}$) during a period of 5 years in the field, and reported excellent removal of TSS, BOD_5 , and fecal coliforms through their system. In addition, Kinsley et al. (2003) suggested 1 to 8 cm/day hydraulic loading rate for the treatment of landfill leachate stating the reason that the hydraulic conductivity of the blank column, which was operated with distilled water, declined from 29 cm/day to 8 cm/day during the 70 days experiment. However, Rock et al. (1984) reported that the degradation of peat and the rate of decomposition observed were more rapid when columns were operated under aerobic condition with tap water than septic tank effluents, because the peat was the only source of carbon when operated with tap water. Rock et al. (1984) also reported that it is important to keep in mind the variability in the BOD_5 concentrations of the influent in defining an appropriate hydraulic loading. In this research, an aeration tank was introduced with a support media for an attached biofilm which might significantly reduced the contaminant load, especially ammonia-N and BOD_5 . Therefore, two different hydraulic loading rates, $8.28 \text{ cm}^3/\text{cm}^2/\text{day}$ (i.e. $650 \text{ mL/day} / (\pi(10)^2/4) \text{ cm}^2$) and 10.82 mL/day (i.e. $850 \text{ mL/day} / (\pi(10)^2/4) \text{ cm}^2$), were considered in this study to evaluate the performance and life expectancy of the peat biofilters.

3.3.2 SAMPLING PROCEDURE

The water quality parameters monitored in the research are summarized in Table 3-2. All samples were preserved and analyzed according to the Standard Methods for the Examination of Water and Wastewater (APHA, AWWA, WEF, 1995). In first phase, the raw leachate was first aerated for 5 days since the HRT of the aeration tank was 5 days. After the 5 day aeration period, continuous feeding of the peat columns with the aerated leachate commenced and continued until clogging of the columns was observed through surface ponding. The sampling began on second day, after feeding of the peat columns had begun. The raw leachate, aerated leachate, and the effluent from the peat columns were the sampling points throughout this study. During the first week, samples were collected and analyzed every day with the exception of CBOD₅ and NO₃-N samples. CBOD₅ was analyzed twice per week for the first month, then once per week until clogging of the peat filters. NO₃-N samples were collected and preserved twice per week for the first 40 days, they were then analyzed after complete laboratory set up for NO₃-N test and continued on a twice per week basis up to the end of first phase.

Table 3-2: Water Quality Parameters

Physical	Organic	Inorganic	Biological
		Ammonia-N (NH ₃ -N)	
		Nitrate-N (NO ₃ ⁻ -N)	
pH	Chemical Oxygen Demand	TSS	Carbonaceous Biochemical Oxygen Demand
Temperature	(COD)	Hydrogen Sulfide (H ₂ S)*	(CBOD ₅)
Flow rate		Boron (B)*	
		Barium (Ba)*	

* Samples were analyzed only in 2-day HRT.

For the second phase, the aerated leachate was fed to the peat biofilter columns after aerating the raw leachate in the aeration basin for 2 days (HRT= 2 days). All the samples, with the exception of hydrogen sulfide (H_2S), boron and barium were collected and analyzed twice per week for the first month, then once per week until the end of the project. For the first month, samples of H_2S were collected and preserved twice per week and then analyzed on a once per week basis until clogging of peat biofilter columns. Samples for boron and barium were collected once per week and preserved according to the Standard Methods (APHA, AWWA, WEF, 1995) and finally analyzed in the Department of Chemistry at Carleton University.

3.3.3 ANALYTICAL METHODS

3.3.3.1 CHEMICAL OXYGEN DEMAND

The chemical oxygen demand (COD) of the samples was analyzed according to the Standard Methods for the Examination of Water and Wastewater (APHA, AWWA, WEF, 1995) using Closed Reflux, Colorimetric Method (Section 5220 D). Borosilicate culture tubes of 16 x 100 mm, a SIP[®] vortex mixer (Cat. No. S8223-1), and a spectrophotometer SPECTRONIC 20D were used for this experiment. The wavelength calibration of the spectrophotometer was verified using the cobalt solution according to the operator's manual (APPENDIX B). Standard calibration curves were prepared according to the procedures prescribed in the method for every new acid reagent, and digestion solution employed during this project (APPENDIX B).

3.3.3.2 BIOCHEMICAL OXYGEN DEMAND

The carbonaceous biochemical oxygen demand (CBOD₅) of the samples was determined according to the Section 5210 B, 5-Day BOD Test, of the Standard Methods for the Examination of Water and Wastewater (APHA, AWWA, WEF, 1995). The CBOD₅ analysis of all the samples was started within 6 hours of sampling. In the experiment, Polyseed-NX capsules were used for carbonaceous BOD determination. An YSI dissolved oxygen meter (model 50B) connected with an YSI Self-Stirring BOD probe (model 5905) was used for measurement of initial and final DO.

3.3.3.3 AMMONIA-N

Ammonia-N (NH₃-N) concentrations were measured using an ammonia probe following standard method 4500 - NH₃ D – Ammonia-Selective Electrode Method (APHA, AWWA, WEF, 1995). A VWR Symphony (model 14002-794) ammonia (NH₃) probe was used for the NH₃-N determination of samples in the liquid phase. The probe has an activity for NH₃-N concentration range between 0.01 to 14000 ppm, a temperature range of 0 to 50° C and reproducibility of ±2 %. The probe was attached to an ORION model 420A pH meter which displayed the corresponding mV of the NH₃-N concentration of the solutions. Ammonia standard solutions were prepared according to the procedure described in Standard Methods for the Examination of Water and Wastewater (APHA, AWWA, WEF, 1995). A standard calibration curve was prepared using standard NH₃ concentrations of 1, 10, 100, 1000 ppm (APPENDIX B).

3.3.3.4 NITRATE- N

The nitrate-N ($\text{NO}_3\text{-N}$) concentrations of the samples were analyzed according to the Standard Methods for the Examination of Water and Wastewater (APHA, AWWA, WEF, 1995) using an ORION-*ionplus* NO_3^- electrode (Section 4500- NO_3^- D). The electrode (model 9700BN) was connected to an ORION pH meter (model 420A), which displayed the corresponding mV of the $\text{NO}_3\text{-N}$ concentration of the test solutions and standards. A standard calibration curve was prepared according to the procedure described in the Standard methods for the Examination of Water and Wastewater (APHA, AWWA, WEF, 1995) for NO_3^- standards of 1, 10, 50, 100, 1000 ppm (APPENDIX B).

3.3.3.5 HYDROGEN SULFIDE

The hydrogen sulfide concentration (H_2S) of the samples was analyzed only for the 2-day HRT study. It was considered as an additional parameter of interest at the end of the 5-day HRT study. Hence, the concentration of H_2S of samples was not measured for the 5-day HRT. For liquid phase H_2S , an ORION Thermo *ionplus* Sure-Flow (model 9616BN) electrode was used according to the Standard Methods for the Examination of Water and Wastewater (APHA, AWWA, WEF, 1995) Section 4500- S^{2-} G (Ion-Selective Electrode Method). The direct measurement procedure was followed according to the electrode manual, where the electrode liner range was greater than 0.32 ppm to 32000 ppm of S^{2-} . An alkaline antioxidant buffer reagent was used to raise the pH above 12, such that HS^- and H_2S were converted to S^{2-} . The concentration of all the sulfide standards was determined by titration with 0.1 M $\text{Pb}(\text{ClO}_4)_2$ solutions. Finally, a standard calibration curve was prepared according to the procedure described in the Standard methods for the

Examination of Water and Wastewater (APHA, AWWA, WEF, 1995) for sulfide standards of 0.088, 0.88, 8.8, 88, 882, 1843 ppm (APPENDIX B).

3.3.3.6 TOTAL SUSPENDED SOLID

The total suspended solids (TSS) of all samples were analyzed according to section 2540 D of Standard Methods for the Examination of Water and Wastewater (APHA, AWWA, WEF, 1995). Whatman filters (model 934-AH), 1.5 μm pore size and 47mm diameter, were used for suspended solid analysis.

3.3.3.7 BORON AND BARIUM

Boron and barium were only analyzed in the samples of the 2-day HRT study, because they were considered parameters of interest in that the end of the 5-day HRT, in order to observe the treatment efficiency of boron and barium through peat filter. The liquid samples were preserved according to the Standard method for the Examination of Water and Wastewater (APHA, AWWA, WEF, 1995), section 3120 B, and were analyzed using ICP in the Department of Chemistry at Carleton University.

3.3.4 OPERATING PARAMETERS

3.3.4.1 pH

The pH of all the samples was monitored using a Corning pH meter model 340, with a temperature operating range of -5 to 105° C and relative accuracy ± 0.01 . The meter was coupled with an Accumet, pH electrode (model 13-620-108). The meter was calibrated

using a two point (buffer solution pH 7 and 10) calibration technique according to the meter's manual, prior to measuring sample pH values.

3.3.4.2 FLOW RATE

The effluent from the peat columns was collected in a set of graduated WHEATON 1000 mL bottles. The volume of the effluents was measured instantly on every sampling day.

3.3.4.3 TEMPERATURE

This bench-scale study was carried in laboratory environment. However, the temperature of all the samples was recorded instantly on the sampling day using a thermometer.

CHAPTER 4

RESULT AND DISCUSSION

4.1 PROPERTIES OF PEAT

The properties of the peat, particle size distribution, moisture content (%), ash content (%), organic matter content (%), bulk density (kg/m^3), and hydraulic conductivity were determined in this study. Appendix B contains the raw data from these experiments. A few larger twigs and clumps of clay were removed by hand before doing the experiments and were, therefore, not included in the results. All of the peat material was sieved for particle size analysis to give a more accurate idea about the size distribution of the peat medium employed in this study.

4.1.1 PARTICLE SIZE DISTRIBUTION

The results of the particle size distribution, shown in Figure 4-1, suggested that the peat used in this study was mostly fine. It included 55% fine ($< 1.18 \text{ mm}$), 26% medium ($< 2.36 \text{ mm}$, $> 1.18 \text{ mm}$), and 19% coarse ($> 2.36 \text{ mm}$) particles. If the particle densities are considered to be the same (i.e. $\rho = \text{constant}$), a 1.18 mm diameter particle would provide double the specific surface area (i.e. surface area/mass) than a 2.36 mm diameter particle for a spherical shape (i.e. surface area $= 4\pi r^2$, mass $= \rho(4\pi r^3/3)$). Therefore, the finer particles could provide more specific surface area for landfill leachate treatment by providing more sites for adsorption processes. This is in agreement with McLellan and Rock's (1988) demonstration, where they reported that peat was a good adsorbent because of its large specific surface area ($> 200 \text{ m}^2/\text{g}$).

Figure 4-1: Particle Size Distribution of Peat Medium

4.1.2 MOISTURE, ASH AND ORGANIC MATTER CONTENT

The moisture, ash and organic matter content of the peat material used in this study were investigated for HRTs of 5-day and 2-day and are presented in Table 4-1. These properties of the peat samples were analyzed on an as received mass basis. In addition, a saturated hydraulic conductivity test for each peat column was conducted, using a constant head set-up, before the start of the leachate treatment study. Hence, the hydraulic conductivity test affected the moisture content of the peat filters. In its use as a biofilter, the moisture content of peat is very important during operation. It affects the degree of microbial activity. At moisture levels greater than 85%, the activity decreases slightly; while below 30% it ceases entirely (Valentin, 1986). The initial moisture content of the peat filter could have a dilution effect on the effluent, which becomes negligible as the filter is operated for an extended period of time.

Table 4-1: Moisture, Ash and Organic Matter Content

Parameter	5-day HRT		2-day HRT	
	Average	St. Dev.	Average	St. Dev.
Moisture Content (%)	51.04	18.45	14.21	0.09
Ash Content (%)	10.46	2.72	15.49	4.98
Organic Matter Content (%)	89.54	2.72	84.51	4.98

The peat moss utilized in this study was found to have a high ash content and correspondingly low organic matter content in comparison to ash contents of 0.5-2.5% (Bergeron, 1994) and organic matter content of 80 to 99 % (Kinsley et al., 2003). The organic matter content correlates well with a number of important physical, chemical, and microbiological properties. As organic matter content increases, soil nutrients such as available nitrogen (N), phosphorus (P), and sulfur (S) increase. There is also a relationship between the soil organic matter content and its bulk density. The density of water is 1000 kg/m³ and mineral soils are usually heavier than water. However, organic soils generally have a bulk density that is lower than water (Orlov, 1992). As the organic matter content of mineral soils increases the bulk density decreases. Consequently, peat materials with higher organic matter content would generally have more functional groups for CEC and would, therefore, be expected to have a higher adsorption capacity for pollutants.

4.1.3 BULK DENSITY

As mentioned in the previous chapter, the emphasis was placed upon the compaction of peat into the column up to a total desired height in the 5-day HRT, but equal weights of peat were used in 2-day HRT. Therefore, a variation in the bulk densities of the peat was observed in the columns for 5-day HRT, and similar densities were observed in 2-day HRT as illustrated in Table 4-2.

The bulk density of peat, in situ, ranges from 20 to 40 kg/m³ at the surface to about 100 kg/m³ at depths of 10 to 30 cm (Clymo, 1983). Bulk densities up to 150 kg/m³ have been reported by Tallis and Switsur (1973). Rock et al. (1984) reported that columns compacted at densities of 150 kg/m³ and greater clogged, confirming the findings of Farnham (1974), who noted that high bulk densities did not allow for adequate percolation. In addition, a bulk density of 100 to 120 kg/m³ (Rock et al., 1984) is typically recommended for optimal performance in domestic wastewater treatment using peat biofilters. This range in density allows for the maintenance of the biofilter matrix and the growth of microorganisms required for treating domestic wastewater. No specific value had been suggested in the literature for the treatment of landfill leachate by peat filters. In this study, the bulk density of the peat columns varied from 289 to 512 kg/m³, which were quite high in comparison with the density range suggested above. Therefore, the saturated hydraulic conductivity of each peat column was determined to confirm adequate percolation of leachate during treatment. The saturated hydraulic conductivity of peat columns was between 13 to 108 cm/hr as discussed in Section 4.1.4, which were 40 to 239 times higher than their average HLR of 0.34 cm/hr (i.e. $8.28 \text{ cm}^3/\text{cm}^2/\text{day} \times$

1/24) and 0.45 cm/hr (i.e. 10.82 cm³/cm²/day x 1/24), which suggested that the dry density of the peat columns allowed for adequate percolation of leachate during treatment operation. The dry density of the peat columns was calculated on a moisture content (APPENDIX A) basis according to Equation 4-1 as presented in Table 4-2.

$$\rho_d = \frac{\rho}{1 + \omega} \quad (4-1)$$

Where ρ , ρ_d , and ω are bulk density (kg/m³), dry density (kg/m³), and moisture content (%) of the peat columns respectively.

Table 4-2: Bulk and Dry Density of Peat Columns for the 5-day and 2-day HRTs:

Column ID		Bulk Density (kg/m ³)		Dry Density (kg/m ³)	
		5-day HRT	2-day HRT	5-day HRT	2-day HRT
Avg. 8.28 cm ³ /cm ² /day HLR	Column 1	512	421	339	369
	Column 2	460	431	305	378
	Column 3	497	433	329	379
Avg. 10.82 cm ³ /cm ² /day HLR	Column 1	513	424	340	372
	Column 2	443	408	293	357
	Column 3	524	411	347	360
Control Column		289	438	191	384

4.1.4 HYDRAULIC CONDUCTIVITY

The saturated hydraulic conductivity of each peat column in both the 5-day and 2-day HRTs was determined using the constant head set-up as illustrated in Table 4-3. The hydraulic conductivities were found to vary between 13 and 108 cm/hr, which represented a variation by a factor of 8. Nichols and Boelter (1982) reported that the hydraulic conductivity of peat can vary by a factor of 5000, depending upon the degree of decomposition. A slightly decomposed fibric peat can have a saturated hydraulic conductivity as high as 140 cm/hr. The hydraulic conductivity of a highly decomposed sapric peat, on the other hand, can be as low as 0.025 cm/hr (Narasiah and Hains, 1988). There is a correlation between the hydraulic conductivity and dry density of peat. Kennedy and Van Geel (2000) reported that the hydraulic conductivity of peat varied log linearly between 14.4 and 284.4 cm/hr over a range of dry densities between 160 and 120 kg/m³. In addition, Champagne (2001) stated the following exponential relationship between the hydraulic conductivity and dry density (ρ_d) of peat from her research.

$$\text{Hydraulic Conductivity (cm/s)} = 25.2 e^{(-0.04\rho_d)} \quad (4-2)$$

However, in this research, emphasis was placed on achieving similar hydraulic conductivities regardless of the dry density. As mentioned previously, the column was compacted up to the total desired height in the 5-day HRT, but same weight of peat (850 g) was used in all columns for the 2-day HRT. Therefore, the hydraulic conductivities of peat with respect to the calculated dry density observed was closer in the 2-day HRT than in the 5-day HRT as shown in Figure 4-2.

Table 4-3: Hydraulic Conductivity of Peat Columns for the 5-day and 2-day HRTs:

Column ID	Hydraulic Conductivity (cm/hr)	
	5-day HRT	2-day HRT
Avg. 8.28 cm ³ /cm ² /day HLR	Column 1	30
	Column 2	18
	Column 3	27
Avg. 10.82 cm ³ /cm ² /day HLR	Column 1	79
	Column 2	58
	Column 3	87
Control Column	108	52

Figure 4-2: Hydraulic Conductivity and Dry Density of Peat Columns for the 5-day and 2-day HRTs

4.2 LEACHATE ANALYSIS

The leachate samples were collected for contaminant analyses during both the 5-day and 2-day HRTs, as discussed in Section 3.3.2. The raw leachate, aerated leachate, and effluents from the peat columns were analyzed for pH, temperature, COD, CBOD₅, TSS, NH₃-N, NO₃⁻-N, H₂S, Boron, Barium, as well as volume of column effluents. The target compounds were analyzed at different sampling points according to the procedures described in Section 3.3.3. The raw data of the analyses for each experiment are included in Appendix B.

4.2.1 CALIBRATION CURVE

The concentration of the COD, NH₃-N, NO₃⁻-N, H₂S were determined from the calibration curves (APPENDIX B), which were prepared from their respective standard as discussed in Section 3.3.3. The spectrophotometer, which was used in COD test, was verified for its wavelength with a calibration curve using cobalt solution as shown in Appendix B. The coefficient of determination (R^2) values for these curves were very high (> 0.95), indicating that nearly linear calibration curves had been achieved which would provide acceptable estimation of the desired concentrations. Table 4-4 presents the R^2 values for each parameter.

Table 4-4: Coefficient of Determination (R^2) Values for the Calibration Curves:

Parameter	R^2 Value
COD	0.9944 ¹
	0.9997 ²
	0.9776 ³
NH ₃ -N	0.9995
NO ₃ ⁻ -N	0.9936
H ₂ S	0.9534

Note: COD Calibration Curves used - ¹From Feb 2, 2004 to Feb 5, 2004, ²From Feb 9, 2004 to Apr 21, 2004, ³From Apr 24, 2004 to End

4.2.2 RAW LEACHATE CHARACTERISTICS

As described in the previous chapter, the raw leachate was collected from the Ottawa Trail Road landfill in a set of plastic containers (28cm X 23cm X 40cm) and was then preserved in refrigerator at 4° C. Each of the containers had a 20 L capacity; therefore, a full container was replaced to supply the system every four days. All of the target components of the raw leachate were generally analyzed on the same sampling day. The results of these analyses are summarized in Table 4-5.

Table 4-5: Raw Leachate Characteristics in 5-day and 2-day HRTs:

HRT	Parameter	Value*		Standard	Number of observations
		Range	Average	deviation (±)	
5-day HRT	Temperature	20.40 - 24	22.79	0.71	40
	pH	6.78 - 8.19	7.36	0.35	40
	CBOD ₅	121 - 575	340	126	16
	COD	556 - 1244	899	176	41
	Ammonia-N	242 - 1018	511	213	36
	Nitrate-N	1 - 4	2	1	27
	TSS	11 - 174	51	40	27
2-day HRT	Temperature	19.50 - 23.50	21.46	1.45	16
	pH	6.94 - 8.04	7.31	0.25	17
	CBOD ₅	337 - 604	534	79	10
	COD	774 - 1395	1052	163	17
	Ammonia-N	307 - 451	392	47	16
	Nitrate-N	1 - 4	2	1	14
	TSS	88 - 166	135	22	12
	H ₂ S	0.11 - 1.88	0.93	0.53	16
	B	3.70 - 6.73	5.67	1.09	10
	Ba	0.14 - 1.38	0.86	0.33	10

* All parameters are expressed in mg/L except pH (no unit) and temperature (°C).

4.3 COLUMN EXPERIMENTS

4.3.1 CONTROL COLUMN

The control peat column was constructed in the same manner as the other peat columns employed in this study and was operated with distilled water under the same environmental conditions as the other experiments. The purpose of the control column was to investigate the behavior of peat under conditions without a landfill leachate influent. The effluent from the control column was collected on each sampling day as described in Section 3.3.2. The effluent was then analyzed for COD, CBOD₅, ammonia-N, nitrate-N, TSS, pH, temperature, and flow rate for both HRTs, as well as H₂S, B and Ba for the 2-day HRT. The results from these analyses are presented in the Table 4-6. It should be noted that the peat column was observed to contribute a significant amount of COD under control condition due to the leaching of humic and fulvic acids resulting from the chemical breakdown of peat, which improved after an extended period of operation. Similar findings were also reported by Rock et al. (1984) in their studies.

Table 4-6: Summary of Control Column Effluent for the 5-day and 2-day HRTs:

HRT	Parameter	Value*		Standard deviation($\pm$)	No. of observation
		Range	Average		
5-day HRT	Temperature	20.50 - 24.50	23.27	0.76	40
	pH	5.88 - 7.43	6.69	0.29	40
	CBOD ₅	3 - 34	15	10	16
	COD	0 - 192	39	43	41
	Ammonia – N	0.24 - 3.60	0.79	0.69	36
	Nitrate-N	0.61 - 4.19	2.31	1.27	27
	TSS	0 - 2.50	0.43	0.67	21
2-day HRT	Temperature	19 - 22.80	20.66	1.14	16
	pH	6.15 - 7.11	6.75	0.27	17
	CBOD ₅	1 - 7	4	2	10
	COD	0 - 120	39	37	17
	Ammonia – N	0.30 - 5.55	2.23	1.47	16
	Nitrate-N	0.44 - 0.69	0.58	0.08	14
	TSS	0.00 - 5.00	1.90	1.66	12
	H ₂ S	0.000-0.010	0.002	0.003	16
	B	0.14 - 0.24	0.19	0.03	10
	Ba	0.004 - 0.015	0.006	0.003	10

* All parameters are expressed in mg/L except pH (no unit) and temperature (°C).

4.3.2 OPERATING PARAMETERS

4.3.2.1 pH

The effluent column pH levels were measured together with the raw leachate and aerated leachate on each sampling day using a Corning pH meter attached to an Accumet, pH electrode (model 13-620-108). The pH of the raw leachate, aerated leachate, and column effluents were plotted as a function of time, as shown in Figure 4-3. After aeration, the pH of the aerated leachate increased from 7.36 to 8.26 for the 5-day HRT, and from 7.31 to 8.38 for the 2-day HRT. This was likely due to the aeration of the leachate, which removed carbon dioxide. Since carbon dioxide is an acidic gas, its removal would tend to decrease $[H^+]$ and thus raise the pH of the water in accordance with Equation 4-3:

Since air contains 0.03 percent CO_2 by volume, the partial pressure of CO_2 in air according to Dalton's law would be 0.3×10^{-3} atm (atmospheric pressure) when the total air pressure is 1 atm in a laboratory environment. In addition, Henry's law constant for CO_2 at 25°C is 1500 mg/L-atm. Therefore, the equilibrium concentration of $\text{CO}_2(\text{aq})$ with air is $(0.3 \times 10^{-3}) \times 1500$ or approximately 0.45 mg/L. Thus, aeration led to the increase in pH to 8.6. At this pH, water with an alkalinity of 100 mg/L reaches equilibrium with the carbon dioxide in the air (Sawyer et al., 1994). A water with a higher alkalinity would tend to have a higher pH upon aeration, and one with lower alkalinity would tend to have a lower pH (Sawyer et al., 1994).

The average pH value of aerated leachate, 8.26 (SD 0.37) for the 5-day HRT and 8.38 (SD 0.29) for the 2-day HRT, fell between the optimal pH range (7.0-8.5) for nitrification (Environment Canada, 2003) and operational pH range (6.5-8.5) for denitrification (Gerardi, 2002), therefore, resulting in the high removal of $\text{NH}_3\text{-N}$ observed for the 5-day HRT and the significant nitrate-N removal at both HRTs. However, an increase in pH might cause more metal precipitation by complex formation, leading to an increase in TSS concentration of the aerated leachate, which ultimately resulted in the clogging of the peat filter.

Figure 4-3: pH of Raw Leachate, Aerated Leachate, and Column Effluents for the 5-day and 2-day HRTs

In this study, the pH levels of all the column effluents were low in comparison with the aerated leachate. This may be due to the leaching of fulvic acids resulting from the

chemical breakdown of peat, which improved after an extended period of operation. (Couillard, 1994; Fuchsman, 1980). Another explanation for this decrease in pH would be the release of protons from the peat material. As mentioned earlier, the acidity of soil solutions is generally caused by the presence of free organic acids or other organic compounds, containing acidic functional groups, free mineral acids (mainly carbonic acid), and other components exhibiting acidic properties (Orlov, 1992). In addition, metals react with the carboxylic and phenolic acid groups of the acids to release proton, thereby decreasing the pH (Brown et al., 2000).

The pH level was observed to increase gradually during the first 20 days from 6.23 to 7.55 and from 6.27 to 7.74 at $8.28 \text{ cm}^3/\text{cm}^2/\text{day}$ and $10.82 \text{ cm}^3/\text{cm}^2/\text{day}$, respectively, for the 5-day HRT. For the 2-day HRT, the pH levels increased from 6.23 to 7.56 at $8.28 \text{ cm}^3/\text{cm}^2/\text{day}$ and from 5.92 to 7.73 at $10.82 \text{ cm}^3/\text{cm}^2/\text{day}$, respectively, after 20 days. Finally, the pH of all column effluents was found to reach steady state as a function of time. In addition, the pH of the control column effluent ranged between 5.88-7.43 and 6.15-7.11 for the 5-day and 2-day HRTs, respectively.

4.3.2.2 TEMPERATURE

The temperature of the raw leachate, aerated leachate, and all column effluents was measured on each sampling day in this study and was plotted as a function of time as presented in Figure 4-4. Since this work was conducted in a laboratory environment, the fluctuations in temperature were not significant. The temperature of the aerated leachate

was found to decrease by approximately 1°C due to aeration, which was then increased through the column effluents.

Figure 4-4: Temperature of the Raw Leachate, Aerated Leachate, and Column Effluents for the 5-day and 2-day HRTs

The temperature of the aerated leachate ranged between 19.50-23 and 18-22 and the column effluents ranged between 20.50-24.50 and 19-22.80 for the 5-day and 2-day HRTs, respectively. However, it should be noted that the temperature of aerated leachate and column effluents fell within the operational temperature range for nitrification (4-45°C) and denitrification but below the optimal temperature range for nitrification (30-35°C) and denitrification.

4.3.2.3 HYDRAULIC LOADING RATE

The volume of flow through each peat columns was collected in a set of graduated plastic bottles placed at the outlet of each of the columns. The volume of the collected effluents was then measured instantly on every sampling day. Finally, the hydraulic flow through rate (HFTR) of each column was calculated by dividing the column area as presented in Appendix B. A summary of the HFTR, for HLRs 8.28 cm³/cm²/day and 10.82 cm³/cm²/day, for the 5-day and 2-day HRTs is presented in Table 4-7. The saturated hydraulic conductivity of peat columns was between 13 to 108 cm/hr as noted in Table 4-3, which were 40 to 239 times higher than their respective average HLRs of 0.34 cm/hr (i.e. 8.28 cm³/cm²/day x 1/24) and 0.45 cm/hr (i.e. 10.82 cm³/cm²/day x 1/24). The HFTR of the columns was found to decrease with time as shown in Figure 4-5, primarily due to the gradual clogging of the peat filter pores, which finally led to failure and surface ponding. Failure was due to the loss in infiltration capacity rather than inability to purify the leachate.

Table 4-7: Hydraulic Loading Rate of Peat Column for the 5-day and 2-day HRTs:

HRT	Column ID	HLR (cm³/cm²/day) Avg. $\pm$ Std. dev.	No. of observations
5-day HRT	Control Column (DW)	9.68 $\pm$ 0.47	35
	Avg. 8.28 cm³/cm²/day	Column 1	7.04 $\pm$ 0.80
		Column 2	7.28 $\pm$ 0.88
		Column 3	7.33 $\pm$ 0.74
			35
	Avg. 10.82 cm³/cm²/day	Column 1	9.23 $\pm$ 1.36
		Column 2	9.63 $\pm$ 1.29
		Column 3	10.07 $\pm$ 0.95
			32
2-day HRT	Control Column (DW)	9.21 $\pm$ 0.20	18
	Avg. 8.28 cm³/cm²/day	Column 1	6.82 $\pm$ 0.76
		Column 2	6.71 $\pm$ 0.60
		Column 3	7.04 $\pm$ 0.65
			18
	Avg. 10.82 cm³/cm²/day	Column 1	9.76 $\pm$ 0.77
		Column 2	9.50 $\pm$ 1.61
		Column 3	10.39 $\pm$ 0.33
			16

Figure 4-5: Hydraulic Loading Rate of Peat Columns for the 5-day and 2-day HRTs

4.3.3 CHEMICAL OXYGEN DEMAND REMOVAL

The chemical oxygen demand (COD) of the raw leachate, aerated leachate, and column effluents was determined using the calibration curve generated from the standard solution. Duplicate samples were analyzed, and the average values of the duplicates were calculated and used to represent the target chemical oxygen demand (COD) values of the raw and aerated leachate, as well as column effluents, and was plotted as a function of time as shown in Figure 4-6.

Throughout each of the two HRTs, the aeration basin did not significantly remove COD from raw leachate. The COD values in the aeration basin were in excess of the raw leachate concentrations, after 94 and 82 days for the 5-day and 2-day HRTs, respectively, which might be due to the contribution of biomass to the COD values. In this research, the sludge in the aeration basin was not removed on a periodic basis, therefore, causing high COD values after an extended period of operation.

The column effluent COD concentrations were found to increase rapidly to influent concentrations after 20 days, and then slowly declined until steady state conditions were reached after approximately 40 days. This increase may have represented a COD contribution to the effluent from the peat itself, sloughing of the biofilm on the peat filter media, or due to the saturation of adsorption capacity of the peat columns. There was no significant difference between the column effluents operated under the two HLR, 8.28 cm³/cm²/day and 10.82 cm³/cm²/day, for both the 5-day and 2-day HRTs.

Figure 4-6: COD of Raw Leachate, Aerated Leachate, and Column Effluents for the 5-day and 2-day HRTs

The cumulative COD influent and cumulative COD removal through peat columns were calculated for both the 5-day and 2-day HRTs as shown in Figure 4-6(a) and 4-6(b). In

both Figure 4-6(a) and 4-6(b), the cumulative COD removal curves followed their corresponding cumulative COD influent curves. For the 5-day HRT, the peat columns found a steady state COD removal up to 81 days, at which point, the influent COD increased because of the higher COD contribution by biomass to the aerated leachate. For the 2-day HRT, the cumulative COD removals were observed to increase gradually until clogging for both HLR of $8.28 \text{ cm}^3/\text{cm}^2/\text{day}$ and $10.82 \text{ cm}^3/\text{cm}^2/\text{day}$, respectively. Finally, an average total cumulative COD removal of 43 and 44 mg/g of peat for HLR $8.28 \text{ cm}^3/\text{cm}^2/\text{day}$ and $10.82 \text{ cm}^3/\text{cm}^2/\text{day}$, respectively were found at the 5-day HRT, and the average total cumulative COD removal of 30 and 43 mg/g of peat for HLR $8.28 \text{ cm}^3/\text{cm}^2/\text{day}$ and $10.82 \text{ cm}^3/\text{cm}^2/\text{day}$ were observed in 2-day HRT.

Figure 4-6(a): Cum. COD Influent and Cum. COD removal through Peat Column for the 5-day HRT

Figure 4-6(b): Cum. COD Influent and Cum. COD removal through Peat Column for the 2-day HRT

The COD concentrations in the effluent of the control peat column ranged between 0-192 mg/L and 0-120 mg/L for HRTs of 5-day and 2-day, respectively, which decreased over time confirming the finding of Rock et al. (1984) that peat itself could leach organic matter to the effluent, a condition which improved with time.

4.3.4 BIOCHEMICAL OXYGEN DEMAND REMOVAL

The carbonaceous biochemical oxygen demand (CBOD₅) concentration of the raw leachate, aerated leachate and column effluents for both HRTs were plotted as a function of time, as shown in Figure 4-7. Throughout each of the two HRTs, the CBOD₅ concentration in the aeration basin was observed to decrease from an average 340 mg/L (SD 126) and 534 mg/L (SD 79) to 98 mg/L (SD 85) and 139 mg/L (SD 85) for the 5-day and 2-day HRTs, respectively. The ratios of the average raw leachate CBOD₅ and COD

values, as presented in Table 4-5, were 0.38 and 0.51 for the 5-day and 2-day HRTs, thus suggesting that a fraction of the leachate was readily biodegradable.

Figure 4-7: CBOD₅ of Raw Leachate, Aerated Leachate, and Column Effluents for the 5-day and 2-day HRTs

The cumulative CBOD₅ influent and cumulative CBOD₅ removal through peat columns for both the 5-day and 2-day HRTs are shown in Figure 4-7(a) and 4-7(b). In both Figures, the cumulative CBOD₅ removal curves followed their corresponding cumulative CBOD₅ influent curves. In the 5-day HRT, the cumulative CBOD₅ removal through the peat columns was found to be negative up to approximately 50 days of operation since the aeration basin contributed to most of the significant removal of CBOD₅ from the raw leachate. The removal through the peat columns then gradually increased as the CBOD₅ loading rate increased due to contribution of biomass from aeration basin. In the 2-day HRT, the cumulative CBOD₅ removals increased gradually until clogging of both HLR 8.28 cm³/cm²/day and 10.82 cm³/cm²/day, respectively, was observed.

Figure 4-7(a): Cumulative BOD Influent and Cumulative BOD removal through the Peat Columns for the 5-day HRT

Figure 4-7(b): Cumulative BOD Influent and Cumulative BOD removal through the Peat Columns for the 2-day HRT

In this study, an average total cumulative CBOD₅ removal of 8.23 and 8.71 mg/g of peat for HLR 8.28 cm³/cm²/day and 10.82 cm³/cm²/day were found for the 5-day HRT, and an average total cumulative CBOD₅ removal of 7.58 and 9.97 mg/g of peat for HLR 8.28 cm³/cm²/day and 10.82 cm³/cm²/day were observed for the 2-day HRT. However, average column effluent CBOD₅ concentrations of 22 mg/L (SD 12) at 8.28 cm³/cm²/day and 24 mg/L (SD 15) at 10.82 cm³/cm²/day were obtained for the 5-day HRT, and 18 mg/L (SD 15) at 8.28 cm³/cm²/day and 29 mg/L (SD 33) at 10.82 cm³/cm²/day for the 2-day HRT were noted, which is relatively close to the minimum US national standards for secondary wastewater treatment (BOD₅ < 30mg/L, CBOD₅ < 25mg/L) (Metcalf and Eddy, 1991).

4.3.5 AMMONIA-N REMOVAL

Ammonia-N concentrations of the raw leachate, aerated leachate, and column effluents for both HRTs of the project are illustrated in Figure 4-8. The ammonia-N concentration was found to decrease significantly in aeration basin through nitrification after approximately two weeks of operation for the 5-day HRT, which suggested that nitrification started relatively quickly when compared to other studies where 1 month had been reported (Welandar, 1997).

In order to establish a large population of nitrifying bacteria, activated sludge processes generally need to operate at a relatively high mean cell residence time (MCRT). The MCRT needed to achieve significant nitrification is usually two to three times the generation time of nitrifying bacteria, which is considered to be two to three days (Gerardi, 2002). Therefore, two weeks of operation were required to achieve significant nitrification, which agreed with the result of this study.

In the 2-day HRT, the ammonia-N concentration of the aerated leachate declined in the same manner as in the 5-day HRT, but started to increase after 45 days. Consequently, lower ammonia-N removal was obtained for the 2-day HRT and ammonia-N removal did not reach a steady-state after two weeks of operation as observed for the 5-day HRT. It would appear that inhibition and toxicity might have been factors affecting nitrification for the 2-day HRT.

Figure 4-8: Ammonia-N of Raw leachate, Aerated leachate, and Column Effluents for the 5-day and 2-day HRTs.

Inhibition of nitrifiers may occur due to the presence of certain inorganic compounds (i.e. un-ionized ammonia, nitrous acid, metals) and organic chemicals (Environment Canada,

2003). The inhibition by free ammonia (toxic ammonia) could be a possibility because of the high ammonia-N concentrations found in the raw leachate. Therefore, the potential for inhibition due to free ammonia was calculated and examined as shown in Figure 4-9 (APPENDIX B).

The p^{K_a} for the ammonia/ammonium equilibrium was calculated for all corresponding temperatures of the sampling day for both the 5-day and 2-day HRTs using Equation 4-5 (Emerson et al., 1975).

$$K_a = \frac{[NH_3][H^+]}{[NH_4^+]} \quad (4-4)$$

$$pK_a = 0.09018 + 2729.92/T \quad (273 \text{ }^\circ\text{K} < T < 323 \text{ }^\circ\text{K}) \quad (4-5)$$

Where T is the temperature in Kelvins.

Theoretically, the fraction (f) of total ammonia that is non-ionized depends upon both water temperature and pH, according to Equation 4-5 and Equation 4-6 (Emerson et al., 1975):

$$f = 1/[10^{(pK_a - pH)} + 1] \quad (4-6)$$

Assuming the activity coefficient as unity, the fraction of free ammonia was calculated. It should be noted that the concentration of NH_3 -N was determined using an ammonia electrode in this study. Therefore, the total ammonia was calculated by multiplying a

factor of 17/14 to get the total ammonia. The free ammonia concentrations of aerated leachate for both the 5-day and 2-day HRTs are shown in Figure 4-9.

Figure 4-9: Total and Toxic Ammonia in HRTs 5-day and 2-day

Inhibition of *Nitrosomonas* by free ammonia can occur at concentrations of 5-150 mg nitrogen/L, while inhibition of *Nitrobacter* is possible at concentrations of 0.1-1 mg nitrogen/L (USEPA, 1993; WEF, 1998). The concentration of toxic ammonia during the period of the 2-day HRT (42 days) was 0.65 mg/L, which was very low to inhibit *Nitrosomonas* but could possibly have inhibited *Nitrobacter*. Another reason might be due to the washout of nitrifying bacteria from the aeration tank at the low HRT of 2 days.

The possibility of ammonia volatilization from liquid phase to gaseous phase was also investigated as a possible mechanism of ammonia removal. Henry's law gives the relationship between the partial pressure of gaseous ammonia and the non-ionized form of ammonia (NH₃) in liquid phase:

$$C_{\text{NH}_3} = K_H * P_{\text{NH}_3} \quad (4-7)$$

Where C_{NH_3} is the concentration of NH₃ gas dissolved in the liquid at equilibrium, P_{NH_3} is the partial pressure of NH₃ gas above the liquid, and K_H is the Henry's law constant. The Henry's law constant for ammonia at 25° C is approximately 298.77 mg/L-atm. Therefore, the equilibrium concentration of NH₃ in the liquid phase at 1 atm is the same as that constant, which is much higher than the concentration of NH₃(aq) shown in Figure 4-9 at the temperature and pH range of this study. These results would suggest that the NH₃-N removal was mainly achieved by nitrification rather than volatilization in the aeration basin, this may be due to the rapid growth of the biofilm onto the attached growth media in the aeration basin for both the 5-day and 2-day HRTs.

In this study, the effluent ammonia-N concentrations of the peat columns were found to increase for the first 2 weeks of operation, at which time they exceeded the influent concentration and started to decline as shown in the Figure 4-8. A steady-state removal efficiency was observed after approximately one month of operation for both HLRs in each of the 5-day and 2-day HRT. As mentioned earlier, the possibility of volatilization of ammonia within the peat column was negligible since the Henry's law constant for ammonia at 25° C is approximately 298.77 mg/L-atm.

Adsorption of NH_4^+ through cation exchange capacity (CEC) is another possible mechanism for ammonia-N removal. Thus, calculations were performed for the adsorption of NH_4^+ as demonstrated in Appendix B. For this purpose, the CEC of the peat for NH_4^+ was considered from the report prepared by Kinsley et al. (2003). As mentioned earlier, they utilized the same peat material in their research. They conducted a CEC test for NH_4^+ and reported an adsorption capacity of 15.5 mg/g for NH_4^+ with Alfred peat. The total adsorption capacity for NH_4^+ of each peat column for both the 5-day and 2-day HRTs was calculated using this data. In addition, the cumulative NH_4^+ concentration of the aerated leachate, the column influent, was calculated. It should be noted that the peat columns were observed to leach ammonia-N after approximately 15 and 21 days for the 5-day and 2-day HRTs, respectively (APPENDIX B). The result of these calculations show that the peat columns were saturated with NH_4^+ before reaching their total adsorption capacity for NH_4^+ except column 2 for the average HLR of $10.82 \text{ cm}^3/\text{cm}^2/\text{day}$ for the 5-day HRT as illustrated in Figure 4-10 and 4-11.

Figure 4-10: Saturation of CEC of Peat Columns for NH_4^+ for the 5-day HRT

Figure 4-11: Saturation of CEC of Peat Columns for NH₄⁺ for the 2-day HRT

The peat columns were found to use an average of 83% and 46% of their total adsorption capacity for NH_4^+ for the 5-day and 2-day HRTs, respectively. These results, therefore, suggest that the effective adsorption capacity for NH_4^+ of the peat column is lower than the adsorption capacity determined from the laboratory adsorption test, which may be a function of compaction of the peat column.

The result from this study agrees Heavey's (2003) demonstration, where he stated that the treatment process for ammonia is temporary storage by cation exchange, followed by release of NH_4^+ from the attached sites, and then nitrification. However, the denitrification process was not discussed as a potential nitrogen removal process (Heavey, 2003). As denitrification was observed in this research, it will be discussed in the following section.

4.3.6 NITRATE-N REMOVAL

The concentrations of nitrate-N (NO_3^- -N) of the raw leachate, aerated leachate, and column effluents were determined using the procedure described in Section 3.3.3.4 and were plotted as a function of time, as shown in Figure 4-12. The NO_3^- -N concentration of aerated leachate gradually increased until approximately 45 days of operation for both HRTs and then started decreasing over time as illustrated in Figure 4-12. This would support the argument that nitrification followed by denitrification was occurring in the aeration basin in both the 5-day and 2-day HRTs. In the absence of oxygen (<1 mg/L), denitrification can occur, where the anaerobic bacteria obtain their oxygen by removing it

from the nitrate (NO_3^-) ion, which acts as an electron acceptor, subsequently leaving nitrogen gas or organic nitrogen compounds. Several intermediates are involved:

Denitrification generally requires anoxic conditions and adequate soluble organic carbon. Figure 4-12 suggests the existences of some anoxic zones in the aeration basin after an extended period of operation. Those anoxic zones might occur at the bottom of the aeration basin and due to sludge accumulation in the tank. In addition, the rapid growth of the biofilm onto the attached growth media in the aeration basin can also provide some anoxic zone for NO_3^- -N removal. As the microorganism grow, the thickness of the biofilm layer increases, and the diffused oxygen is consumed before it can penetrate the full depth of the biofilm layer. Thus, an anaerobic environment can be established near the surface of the media, which was mainly responsible for the NO_3^- -N removal in the aeration basin after an extended period of operation. Although several groups of organisms are capable of denitrification, including fungi and the protozoa Loxodes, most denitrifying organisms consist of facultative anaerobic bacteria. The bacteria that denitrify are known by several names including denitrifiers, heterotrophs, and organotrophs (Gerardi, 2002).

The most critical factors are the presence of a substrate or readily available carbon source, which was likely as high as the CBOD_5 concentrations in the raw leachate, as well as the absence of free molecular oxygen, which might occur in some anoxic zones. The NO_3^- -N concentration in the aeration basin was reduced from a peak value of 319

mg/L after 44-days to 90 mg/L at the end through denitrification during the 5-day HRT study. In the 2-day HRT, NO_3^- -N concentration in the aeration basin was reduced from 96 mg/L after 42-days to 1.07 mg/L at the end, resulting in an excellent removal of NO_3^- -N through denitrification.

Figure 4-12: Nitrate-N of Raw Leachate, Aerated Leachate, and Column Effluents for the 5-day and 2-day HRTs

In this study, the NO_3^- -N concentrations of the column effluents were found to increase dramatically until 49 and 36 days of operation, and then started decreasing over time for both HLRs for the 5-day and 2-day HRTs, respectively, as illustrated in Figure 4-12. In the 5-day HRT, the NO_3^- -N concentrations of the peat columns were reduced from peak values of 299mg/L (day 44) (SD 26) to 115mg/L (end) (SD 18) and from 336mg/L (day 44) (SD 20) to 109mg/L (end) (SD 7) for HLRs of $8.28 \text{ cm}^3/\text{cm}^2/\text{day}$ and $10.82 \text{ cm}^3/\text{cm}^2/\text{day}$, respectively. In the 2-day HRT, NO_3^- -N concentrations were reduced from 132 mg/L (day 36) (SD 11) to 48mg/L (day 72) (SD 0.14) for the $8.28 \text{ cm}^3/\text{cm}^2/\text{day}$ HLR, and from 150 mg/L (day 36) (SD 18) to 37 mg/L (day 82) (SD 21) for the $10.82 \text{ cm}^3/\text{cm}^2/\text{day}$ HLR.

The column effluent concentrations did not provide a clear indication of NO_3^- -N removal since they simply followed the aerated leachate concentration curve. Therefore, calculations were conducted for the generation of NO_3^- -N (mg/L) as a function of time for both HRTs as shown in Figures 4-13 and 4-14. Figures 4-13 and 4-14 suggest that the peat columns started generating NO_3^- -N at 40 and 28 days for the 5-day and 2-day HRTs, respectively, which gradually increased until days 49 and 36, when they finally declined until the end of the experiment. Therefore, from these results, it would appear that denitrification was not established to begin removing NO_3^- -N in the peat filters until days 49 and 36, respectively. In addition, the aeration basin was mainly responsible for the removal of NO_3^- -N through denitrification throughout this study. This may be due to the rapid growth of the biofilm onto the attached growth media in the aeration basin. However, denitrification requires a specific environment to perform NO_3^- -N removal

including; anoxic conditions ($\text{DO} < 1 \text{ mg/L}$) and adequate soluble organic carbon. Moreover, peat itself contains high organic carbon which could be used in the denitrification process. However, if peat were used as the carbon source, then the decomposition of the peat would be accelerated, thereby decreasing the longevity of the filter bed. The development of the anoxic zones may be a function of the length of peat column, its density, as well as HLR. In this work, the bulk densities of peat columns were between $408\text{--}524 \text{ kg/m}^3$ which were quite high in comparison with the $100\text{--}120 \text{ kg/m}^3$ suggested by Rock et al. (1984), where they noted that denitrification is main removal mechanism for nitrogen removal. Even at the high peat densities in the columns utilized in this study, the data would suggest that denitrification would have started after one and half month following start up.

Figure 4-13: Nitrate-N Generation in Aeration Basin and Peat Columns for the 5-day HRT

2-day HRT:

Figure 4-14: Nitrate-N Generation in Aeration Basin and Peat Columns for the 2-day HRT

4.3.7 HYDROGEN SULFIDE REMOVAL

The liquid-phase hydrogen sulfide (H_2S) of the raw leachate, aerated leachate, and column effluents were measured only for the 2-day HRT using an ORION Thermo *ionplus* Sure-Flow electrode as described in Section 3.3.3.5. The Standard Method for the Examination of Water and Wastewater (APHA, AWWA, WEF, 1995), Section 4500- S^{2-} was employed to measure the total S^{2-} concentration in the liquid; and, further calculation were performed to determine the H_2S concentration, based on the pH and temperature of the samples (APPENDIX B). Dissociation of the H_2S is described by the following two equations:

Where K_{a1} and K_{a2} are the equilibrium constants for these two equations.

The pH of the aerated leachate ranged between 8.11- 8.93 for the 2-day HRT. At pH values of 8 and above, most of the reduced sulfur exists in solution as HS^- and S^{2-} ions, and the amount of free H_2S is so small that its partial pressure is insignificant. Therefore, volatilization of H_2S was not considered to be plausible under these conditions. In addition, the concentration of H_2S in the raw leachate ranged between 0.11 – 1.88 mg/L, as noted in Table 4-5, which would suggest that, at this low level, H_2S was removed as a function of oxidation by aeration for the 2-day HRT as illustrated in Figure 4-15.

Figure 4-15: H_2S of Raw and Aerated Leachate for the 2-day HRT

In addition, the concentrations of H_2S of the aerated leachate and the column effluents were plotted as shown in Figure 4-16. The possible mechanisms of H_2S removal by peat include volatilization, adsorption, and bio-chemical oxidation (McNevin et al., 1998). The aeration basin removed much of the H_2S from the raw leachate and brought the H_2S concentration to an average 0.005 mg/L as illustrated in Table 4-15. As such, it was not possible to further examine the actual mechanisms of H_2S removal by peat filter from this study within the scope of this project.

Figure 4-16: H_2S of Aerated Leachate, and Column Effluents for the 2-day HRT

4.3.8 TOTAL SUSPENDED SOLID REMOVAL

The total suspended solid (TSS) concentrations of the raw leachate, aerated leachate, and column effluents were determined according to the procedure described in Section 3.3.3.6 and are presented in Figure 4-17 for each HRT of the study.

Figure 4-17: TSS of Raw Leachate, Aerated Leachate, and Column Effluents for the 5-day and 2-day HRTs

Throughout the experiment, the TSS concentration of the aerated leachate was observed to decrease prior to day 70 and 78 for the 5-day and 2-day HRTs, respectively. At that

point the TSS concentration of aerated leachate exceeded the raw leachate TSS concentration as shown in Figure 4-17. This may be due to higher metal precipitation as a result of the pH increase to 8.3 in the aerated leachate, as well as the washout of sludge from the aeration basin. This could potentially lead to the clogging of the peat biofilter. Similar findings were reported by Cameron (1978), who demonstrated that with an increase in pH to 8.4, non-filterable residue increased from 105 to 312 mg/L. This led to the formation of precipitated metal complexes, and subsequently, resulted in the clogging of the surface pores of the peat column.

As discussed earlier, a spun plastic attached growth media was used in the aeration basin, which had a very large surface area and texture for promoting the rapid growth of a biofilm. This biofilm might provide an advantage for the removal of suspended solid in the aeration basin at an earlier stage for both the 5-day and 2-day HRTs because of the adsorption of suspended solid onto the biological film layer attached to the media. Moreover, it should be mentioned that the sludge in the aeration basin was not removed on a periodic basis throughout either of the HRTs of this study. Therefore, the higher TSS concentrations of aerated leachate after 70 and 78 days for the 5-day and 2-day HRTs, respectively, might potentially cause the clogging of the peat biofilter.

In this study, the peat columns were found to have an average effluent TSS concentration of 9mg/L (SD 9) at 8.28 cm³/cm²/day and 6mg/L (SD 7) at 10.82 cm³/cm²/day for the 5-day HRT. For the 2-day HRT, average effluent TSS concentrations of 34 mg/L (SD 12) at 8.28 cm³/cm²/day and 42 mg/L (SD 18) at 10.82 cm³/cm²/day were observed. The

main mechanism of TSS removal is physical filtration because of the porous nature of the material, which provided excellent filtration of solid particles until clogging. The cumulative TSS influent and cumulative TSS removal through the peat columns are illustrated in Figure 4-17(a) and 4-17(b) for both the 5-day and 2-day HRTs, respectively. In both figures, the cumulative TSS removal curves followed their corresponding cumulative TSS influent curves. For the 5-day HRT, the influent TSS loading was very low until day 54 of operation, which then suddenly increased because of higher TSS contributions by the aeration basin itself, and finally causing the clogging of the peat columns. This may suggest that the lower TSS loading at the initial stage significantly increased the total operational life of the peat biofilter for the 5-day HRT when compared to that of the 2-day HRT. For the 2-day HRT, the cumulative TSS removals gradually increased, which followed the influent TSS loading, until clogging of both HLR 8.28 $\text{cm}^3/\text{cm}^2/\text{day}$ and 10.82 $\text{cm}^3/\text{cm}^2/\text{day}$, respectively, had occurred.

Figure 4-17(a): Cum. TSS Influent and Cum. TSS removal through Peat Column for the 5-day HRT

**Figure 4-17(b): Cum. TSS Influent and Cum. TSS removal through Peat Column
for the 2-day HRT**

Finally, an average total cumulative TSS removal of 13.93 mg/g of peat and 15.35 mg/g of peat for HLR 8.28 cm³/cm²/day and 10.82 cm³/cm²/day were found for the 5-day HRT, and an average total cumulative TSS removal of 2.85 mg/g of peat and 3.26 mg/g of peat for HLR 8.28 cm³/cm²/day and 10.82 cm³/cm²/day were observed for the 2-day HRT.

4.3.9 BORON AND BARIUM REMOVAL

After completion of the 5-day HRT study, the removal performance of peat for boron (B) and barium (Ba) were investigated for the 2-day HRT. As such, B and Ba samples were collected and preserved on a weekly basis only during the 2-day HRT of this study. The samples were tested using ICP in the Department of Chemistry at Carleton University.

Finally, the concentrations of B and Ba were plotted as a function of time as illustrated in Figure 4-18 and 4-19. The removal of either boron or barium in the aeration basin was not significant in this study. However, there was a possibility of Ba complex formation and precipitation because of the formation of sulfate complexes at high pH levels in the aerated leachate basin.

Figure 4-18: Boron Concentration of Raw Leachate, Aerated Leachate, and Column Effluents for the 2-day HRT

Figure 4-19: Barium Concentration of Raw Leachate, Aerated Leachate, and Column Effluents for the 2-day HRT

Boron is a non-metal element; therefore, it was assumed that the removal of boron via adsorption by peat was negligible. However, Sartaj (2001) reported that the adsorption of boron through peat is pH dependent. At acidic pH levels (<7.0), boron is mainly present as molecular boric acid, thus leaching through peat. As the pH increases, $B(OH)_4^-$ concentrations also increase, resulting in higher adsorption. In addition, Baohua and Lowe (1990) reported that boron adsorption by humic acid generally peaks at a pH of 9. Kinsley et al. (2003) conducted an adsorption experiment using this peat material, and observed an adsorption capacity of 0.31 mg B per g peat (mg/g). The total boron adsorption capacity of each peat column for the 2-day HRT study was 226 mg, since each of the peat columns contained approximately 850 g peat with a moisture content of 14.21%. In addition, the average B concentration of the aerated leachate was 5.69 mg/L.

Therefore, the total amount of boron in the column influent was 3.69 mg/day (i.e. 5.69 mg/L x 650 mL/day x (1L / 1000mL)) and 4.83 mg/day (i.e. 5.69 mg/L x 850 mL/day x (1L / 1000mL)) for the 8.28 cm³/cm²/day and 10.82 cm³/cm²/day HLR, respectively. This would suggest that the peat column should have become saturated with boron within 61 days and 46 days for the 8.28 and 10.82 cm³/cm²/day HLRs, respectively. However, the peat columns were found to be leaching of boron within 42 and 28 days for the 8.28 and 10.82 cm³/cm²/day HLRs, respectively. In addition, the cumulative boron removal of the peat columns on the day breakthrough was observed were calculated and summarized in the following Table 4-8.

Table 4-8: Summary of Boron Break Through of Peat Columns in 2-day HRT

Phase	Column ID	Breakthrough Observed (day)	Cumulative Boron Removal (mg/ g of Peat)
2-day HRT	Controlled Column(DW)	-	-
	Avg. 8.28 cm ³ /cm ² /day	Column 1	0.100
		Column 2	0.118
		Column 3	0.085
	Avg. 10.82 cm ³ /cm ² /day	Column 1	0.096
		Column 2	0.122
		Column 3	0.054

These results would suggest that the effective boron adsorption capacity of the peat column is lower than the adsorption capacity determined from the laboratory adsorption experiments. Whereas a steady-state barium removal efficiencies through the peat filters were investigated and presented in Figure 4-20. The Ba removal through the peat

columns might be due to adsorption of Ba onto peat as well as removal of metal complexes through filtration.

Figure 4-20: Barium Removal Percentage by Peat Column for the 2-day HRT

4.4 SUMMARY OF RESULTS

The effectiveness of peat biofilters and their potential clogging are very important in terms of organic (COD, BOD₅), ammonia-N, nitrate-N, and TSS loading, as well as hydraulic loading rate (HLR). Therefore, a sequential aerated peat biofilter laboratory system was initiated on October 3rd 2003 and was operated in two different phases. The first phase involved a 5-day HRT in the aeration tank with constant air flow rate of 3.40 m³/d, while in second phase, a 2-day HRT was employed for the same air flow rate. In addition, two set of triplicate peat columns were operated at HLRs of 8.28 cm³/cm²/day and 10.82 cm³/cm²/day, respectively, for both HRTs of this study.

The properties of the peat, particle size distribution, moisture content, ash content, organic matter content, bulk density, as well as saturated hydraulic conductivity were determined. The results from those analyses suggested that the peat used in this study consisted mostly of fine particles (55% fine particles). Columns were packed to bulk densities ranging between 289 and 524 kg/m³, and having corresponding hydraulic conductivities ranging from 13 to 108 cm/hr. The larger number of fine particles provided more sites for adsorption, However, the longevity of the columns was limited by the high bulk densities. In addition, the peat columns were operated at hydraulic loading rates of 0.34 cm/hr (i.e. 8.28 cm³/cm²/day x 1/24) and 0.45 cm/hr (i.e. 10.82 cm³/cm²/day x 1/24), which were 40 to 239 times lower than their saturated hydraulic conductivities.

The contaminant load in the Trail Road landfill leachate was much higher than is typically reported for untreated domestic wastewater especially in terms of the higher

ammonia-N, TSS, COD, and BOD₅ concentrations. The average influent COD, CBOD₅, ammonia-N, nitrate-N, and TSS concentrations were 899mg/L (SD 176), 340mg/L (SD 126), 511mg/L (SD 213), 2mg/L (SD 1), and 51mg/L (SD 40) for the 5-day HRT. In addition, the average influent COD, CBOD₅, ammonia-N, nitrate-N, and TSS concentrations were 1052mg/L (SD 163), 534mg/L (SD 79), 392mg/L (SD 47), 2mg/L (SD 1), and 135mg/L (SD 22) for the 2-day HRT. Therefore, the high contaminant concentrations of the Trail Road landfill leachate indicated that the leachate is a high-strength wastewater in comparison with municipal wastewater.

The results of this study showed that the aeration basin was not able to significantly remove COD from the raw leachate for both the 5-day and 2-day HRTs, respectively. On the other hand, the CBOD₅ concentration in the aeration basin was observed to decrease from an average 340 mg/L (SD 126) and 534 mg/L (SD 79) to 98 mg/L (SD 85) and 139 mg/L (SD 85) for the 5-day and 2-day HRTs, respectively. Excellent steady-state removal of NH₃-N was observed for the higher HRT of 5 days after approximately two weeks of operation, whereas, similar NH₃-N removal was not observed for the 2-day HRT after approximately three weeks of operation. The higher 5-day HRT also led to better nitrification than the 2-day HRT. In addition, an average NO₃⁻-N generation of 108 mg/L was found for HRT of 5 days compared to 21 mg/L for HRT of 2 days. Denitrification was also noted in the aeration basin after 44 and 42 days of operation for the 5-day and 2-day HRTs, respectively. The aeration basin was mainly responsible for NO₃⁻-N removal due to the rapid formation of the biofilm onto the attached growth media in the aeration basin. As the microorganism grow, the thickness of the biofilm layer increases, and the

diffused oxygen is consumed before it can penetrate the full depth of the biofilm layer. Thus, an anaerobic environment was established near the surface of the media, which might be the main mechanism for the NO_3^- -N removal in the aeration basin after an extended period of operation. The concentration of NO_3^- -N was observed to decrease from 319 mg/L (day 44) and 96 mg/L (day 42) to 90 mg/L (end) and 1 mg/L (end) for the 5-day and 2-day HRTs, respectively.

The TSS concentration of aerated leachate was observed to decrease prior to days 70 and 78 for the 5-day and 2-day HRTs, respectively. After that the TSS concentration of aerated leachate exceeded that of the raw leachate TSS concentration, which might be due to the fact that sludge in the aeration basin was not collected and disposed of throughout the course of each experimental run. In addition, higher metal precipitation was a possibility because of the increase in pH from 7.36 and 7.31 to 8.24 and 8.38 for the 5-day and 2 day HRTs, respectively. As described previously, the concentration of H_2S , B and Ba were monitored only for the 2-day HRT, as additional objectives of this research. The results from those analyses showed that complete removal of H_2S from an average of 0.926 mg/L (SD 0.526) to 0.005 mg/L (SD 0.006) was achieved as a result of H_2S oxidation in the aeration basin, while boron and barium removal were not significant in the aeration basin.

In this study, two sets of triplicate columns were operated at HLRs of $8.28 \text{ cm}^3/\text{cm}^2/\text{day}$ and $10.82 \text{ cm}^3/\text{cm}^2/\text{day}$, respectively, for both the 5-day and 2-day HRTs. The average of the triplicate columns was used in the presentation of the results and their ultimate

evaluation. The results of this study demonstrated that the effluent of the peat columns had average COD of 356 mg/L (SD 275) and 383 mg/L (SD 287) at the HLRs 8.28 cm³/cm²/day and 10.82 cm³/cm²/day, respectively, for the 5-day HRT; while, an average effluent COD of 413 mg/L (SD 299) and 415 mg/L (SD 340) were observed for the 2-day HRT at the same HLRs. Peat itself contributed COD to the effluents which was confirmed by the effluent COD concentrations from the control column, an average of 39 mg/L (SD 43) and 39mg/L (SD 37) for the 5-day and 2-day HRTs, respectively. As a consequence, the overall removal of COD was not high. The CBOD₅ removals were achieved due to the biodegradation of organic matter in the peat system. Average effluent CBOD₅ concentrations of 22 mg/L (SD 12) and 24 mg/L (SD 15) for 8.28 cm³/cm²/day and 10.82 cm³/cm²/day, respectively were noted for the 5-day HRT, and 18 mg/L (SD 15) and 29 mg/L (SD 33) were obtained for the 2-day HRT, for the 8.28 cm³/cm²/day and 10.82 cm³/cm²/day HLRs, respectively. Comparatively, effluent NH₃-N concentrations were less than 2.18 mg/L and 2.15 mg/L after one month of operation for the 5-day HRT, and were less than 4.29 mg/L and 5.30 mg/L after 36 days of operation which increased at the end before clogging for the 2-day HRT, were found at 8.28 cm³/cm²/day and 10.82 cm³/cm²/day, respectively. The suspected main mechanisms of NH₃-N removal were adsorption of NH₄⁺ onto peat up to the saturation of adsorption capacity for NH₄⁺, followed by leaching of NH₃-N, and finally nitrification and denitrification. An average, NO₃⁻-N concentrations of 121 mg/L (SD 84) and 119mg/L (SD 89) for the 5-day HRT, and 38 mg/L (SD 39) and 48mg/L (SD 45) for the 2-day HRT were observed for the HLRs of 8.28 cm³/cm²/day and 10.82 cm³/cm²/day, respectively. Denitrification in the

peat column was believed to have begun after 49 and 36 days of operation; this might be due to some anoxic zones formation at the bottom of the column.

Average effluent TSS concentrations of 9mg/L (SD 9) and 6mg/L (SD 7) for the 5-day HRT, and 34 mg/L (SD 12) and 42 mg/L (SD 18) for the 2-day HRT, were found for the HLRs of 8.28 cm³/cm²/day and 10.82 cm³/cm²/day, respectively. TSS removal was achieved through adsorption and physical filtration via its porous structure. Complete removal of H₂S was achieved due to the oxidation of H₂S in the aeration basin. Moreover the peat column brought H₂S concentrations down to zero. Removal of B did not continue for a long period of time because of saturation of adsorption capacity for B adsorption, and leaching of boron through peat columns were found within 42 and 28 days for the 8.28 and 10.82 cm³/cm²/day HLRs, respectively. Average removal of Ba 80% (SD 28) and 89% (SD 14) were achieved for the 2-day HRT for the 8.28 cm³/cm²/day and 10.82 cm³/cm²/day HLRs, primarily due to the CEC of peat and the filtration of metal complexes through the peat matrix.

One of the main objectives of this research was to investigate the total lifetime of the peat biofilter system under varied contaminant loadings, in terms of the HRT in the aeration basin, as well as the hydraulic loading rate. As mentioned earlier, the raw leachate was aerated for 5 and 2 days prior to the start of feeding the peat column; therefore, these operational times in aeration basin were not considered in the calculations of the overall operational life of the peat filters. The operational life of each of the peat filters was considered to lie between the days when feeding of the peat columns with leachate commenced to the time clogging was observed as exhibited by surface ponding. In

addition, two sets of triplicate columns were used for this assessment, and the total cumulative COD, CBOD₅, and TSS removal within the peat columns at the end of the experimental runs were also calculated under these different operational conditions, as presented in Table 4-9.

Table 4-9: Total Life and Cumulative Contaminants Removal of Peat Filters:

Phase	Column		Total Operational Life (day)	Cumulative Removal (mg/ g of Peat)		
	ID			COD	BOD	TSS
5-day HRT	Controlled Column(DW)		No Clogging	—	—	—
	Avg. 8.28 cm ³ /cm ² /day	Column 1	104	34.68	6.42	10.92
		Column 2	108	46.88	9.42	15.28
		Column 3	115	48.12	8.86	15.59
	Avg. 10.82 cm ³ /cm ² /day	Column 1	108	41.31	7.54	14.96
		Column 2	101	48.74	10.42	16.71
		Column 3	101	42.06	8.17	14.37
2-day HRT	Controlled Column(DW)		No Clogging	—	—	—
	Avg. 8.28 cm ³ /cm ² /day	Column 1	82	30.04	7.65	2.91
		Column 2	64	20.90	5.51	1.40
		Column 3	93	37.79	9.57	4.23
	Avg. 10.82 cm ³ /cm ² /day	Column 1	93	51.68	13.50	5.20
		Column 2	64	31.10	5.80	1.32
		Column 3	82	46.77	10.60	3.26

A single factor ANOVA (Analysis of Variance) test was conducted with an alpha value of 0.05 for statistical comparison between the performances of the peat columns operated under different conditions. The results of this study indicated that statistically similar total cumulative organic (COD, CBOD₅) removal of peat columns were observed under different HLRs and HRTs since F values were always less than F_{critical} values in ANOVA test as noted in Appendix B. However, the higher 5-day HRT of aeration basin increased

the operation life of peat biofilters compared to the 2-day HRT by lowering the contaminant loading onto peat biofilters.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

A sequential aerated peat biofilter system was developed and evaluated for the treatment of landfill leachate under varying contaminant loadings, in term of the HRT in the aeration chamber, and hydraulic loading rates. This system consisted of two major components: an aeration chamber with an attached growth media, which has a large surface area and texture which could promote the rapid growth of a biofilm, and two sets of triplicate peat columns operated at different hydraulic loading rates. This research was conducted in two different phases. In first phase, the raw leachate was aerated in the aeration basin for a 5-day HRT and a constant air flow rate of 3.40 m³/d, while in second phase a 2-day HRT was employed for the same air flow rate. Two sets of triplicate peat columns were operated at average HLRs of 8.28 cm³/cm²/day and 10.82 cm³/cm²/day in both HRTs 5-day and 2-day.

Since peat is a highly variable material, the examination for the properties of peat was conducted to provide a basis for the comparison of performance of peat filters under different contaminants and hydraulic loading conditions. The *Sphagnum* peat moss utilized in this research was mostly fine (55 % fine particles), with a high ash content (ash content > 10 %) and highly dense (191kg/m³ < dry density < 384 kg/m³). The hydraulic conductivities of the peat columns ranged between 13 cm/hr and 108 cm/hr. In addition, the Trail Road landfill leachate used in this research was considered to be a high

strength wastewater especially in terms of the ammonia-N ($511\text{mg/L} \pm 213$ in 5-day HRT, and $392\text{mg/L} \pm 47$ in 2-day HRT), TSS ($51\text{mg/L} \pm 40$ in 5-day HRT, and $135\text{mg/L} \pm 22$ in 2-day HRT), COD ($899\text{ mg/L} \pm 176$ in 5-day HRT, and $1052\text{mg/L} \pm 163$ in 2-day HRT), and CBOD₅ ($340\text{mg/L} \pm 126$ in 5-day HRT, and $534\text{mg/L} \pm 79$ in 2-day HRT) concentrations.

The results of this study showed that the aeration basin did not significantly remove COD from the raw leachate for both the 5-day and 2-day HRTs, respectively. On the other hand, the CBOD₅ concentrations in the aeration basin were observed to decrease from an average 340 mg/L (SD 126) and 534 mg/L (SD 79) to 98 mg/L (SD 85) and 139 mg/L (SD 85) for the 5-day and 2 day HRTs, respectively. A steady-state removal of NH₃-N was observed for the higher HRT of 5 days after approximately two weeks of operation, whereas, NH₃-N removal was not significant for 2-day HRT after approximately three weeks of operation, which suggested that higher 5-day HRT also provided for better nitrification than the 2-day HRT. In addition, an average NO₃⁻-N generation of 108mg/L (SD 76) was found for the 5-day HRT compared to 21 mg/L (SD 28) for the 2-day HRT. Denitrification began in the aeration basin after 44 and 42 days of operation for the 5-day and 2-day HRTs, respectively. The NO₃⁻-N concentration was found to decrease from 319mg/L (day 44) and 96 mg/L (day 42) to 90mg/L (end) and 1mg/L (end) for the 5-day and 2-day HRTs, respectively. These results indicated that HRT was a limiting factor affecting the contaminant removal efficiencies of the aeration basin. Therefore, an increase in HRT would increase the removal of contaminants. In addition, the complete removal of H₂S from an average of 0.926 mg/L (SD 0.526) to 0.005 mg/L (SD 0.006)

was achieved from the oxidation of H_2S in the aeration basin, while boron and barium removal were not significant in the aeration basin for the 2-day HRT.

The results from 5-day HRT showed that the average COD, CBOD_5 , and TSS concentrations of peat biofilter effluents were 356 mg/L (SD 275), 22 mg/L (SD 12), 9 mg/L (SD 9) for HLR $8.28 \text{ cm}^3/\text{cm}^2/\text{day}$, whereas, they were 383 mg/L (SD 287), 24 (SD 15), and 6mg/L (SD 7) for HLR of $10.82 \text{ cm}^3/\text{cm}^2/\text{day}$. The 2-day HRT results showed that the average COD, CBOD_5 , and TSS concentrations of peat biofilter effluents were 413 mg/L (SD 299), 18 mg/L (SD 15), and 34 mg/L (SD 12) for HLR $8.28 \text{ cm}^3/\text{cm}^2/\text{day}$, whereas, they were 415 mg/L (SD 340), 29 mg/L (SD 33), and 42 mg/L (SD 18) for HLR of $10.82 \text{ cm}^3/\text{cm}^2/\text{day}$. In addition, the effluent $\text{NH}_3\text{-N}$ concentrations were less than 2.18 mg/L and 2.15 mg/L for HLR of $8.28 \text{ cm}^3/\text{cm}^2/\text{day}$ and $10.82 \text{ cm}^3/\text{cm}^2/\text{day}$ after one month of operation for the 5-day HRT, and they were less than 4.29 mg/L and 5.30 mg/L for HLR of $8.28 \text{ cm}^3/\text{cm}^2/\text{day}$ and $10.82 \text{ cm}^3/\text{cm}^2/\text{day}$ after 36 days of operation and proceeded to increase at the end before clogging for the 2-day HRT. The peat column started generating $\text{NO}_3^- \text{-N}$ at 44 and 28 days for the 5-day and 2-day HRTs, respectively, which continued until days 49 and 36, then finally declined until the completion of the experiment. The removal of H_2S , B, and Ba was monitored only for the 2-day HRT. Since most of the removal H_2S occurred in the aeration basin, the mechanisms of H_2S removal through peat filter were not clear and were considered to be negligible in this study. The removal of B did not continue for a long period because of reaching the saturation of adsorption capacity for B adsorption. However, the peat filter columns were observed to remove an average of 80% (SD 28%) and 89% (SD 14%) of Ba for 8.28

$\text{cm}^3/\text{cm}^2/\text{day}$ and $10.82 \text{ cm}^3/\text{cm}^2/\text{day}$ HLRs through the adsorption and filtration of metal complexes. These results, suggested that the contaminant removal efficiencies of the peat biofilter columns were similar for these different HLRs of $8.28 \text{ cm}^3/\text{cm}^2/\text{day}$ and $10.82 \text{ cm}^3/\text{cm}^2/\text{day}$ HLRs.

The results indicated that the peat columns were unstable during the first month of operation, since the leaching of COD by the peat and saturation of adsorption capacity for ammonia-N followed by leaching of ammonia-N was observed during this time. Therefore, adsorption of contaminants should not be considered as a main removal mechanism if long-term operation is desired. The aeration basin was primarily responsible for the removal of $\text{NH}_3\text{-N}$ and $\text{NO}_3^-\text{-N}$ through nitrification and denitrification. Steady-state nitrification commenced in the aeration basin after approximately 2 to 3 weeks of operation, perhaps due to the fact that it takes 2-3 weeks for the establishment of a relatively steady-state biofilm on the attached growth media which was mainly responsible for $\text{NH}_3\text{-N}$ removal. As the microorganisms grow, the thickness of the biofilm layer increases, and the diffused oxygen is consumed before it can penetrate the full depth of the biofilm layer. Therefore, an anaerobic environment was established near the surface of the media, which was mainly responsible for the denitrification in aeration basin after about one and half month of operation for both the 5-day and 2-day HRTs. Aeration of the leachate gave the advantage of raising the pH of aerated leachate, from 7.40 to 8.24 for the 5-day HRT and from 7.29 to 8.26 for the 2-day HRT, by removing CO_2 from the leachate. Consequently, the possibility of higher metal precipitation due to the formation of metal complexes might have increased the TSS

concentration of the aerated leachate. Finally, clogging of the surface pores of the peat filters was possibly experienced because of the limited management of the solids of the aeration basin.

One of the main objectives of this research was to investigate the total operational life of the peat biofilter under varied contaminant loading and hydraulic loading rates. The contaminant loadings to the peat columns were considered to be a function of the HRT in the aeration basin. The results of this research showed that the impact of the hydraulic loading rate was less significant than the effect of contaminant loading rate leading to a longer life of the peat filters. Statistically similar organic (COD, CBOD₅) removal performances and life expectancies could be obtained from the two different hydraulic loading rates of 8.28 cm³/cm²/day and 10.82 cm³/cm²/day for both the 5-day and 2-day HRTs. However, the higher hydraulic retention time of 5 days increased the life expectancy of the peat biofilter, by approximately one month, due to the considerable decrease in the organic, ammonia-N, and TSS loading as a result of extended aeration.

5.2 RECOMMENDATIONS

A bench-scale sequential aerated peat biofilter system was operated for a total 115 days for the 5-day HRT and a total of 93 days for the 2-day HRT in this research. Much of this thesis work focused on the contaminant and hydraulic loading rates of the peat filter columns, because those were the least understood and considered to present the greatest uncertainty in term of removal efficiencies and life expectancies of the peat biofilter system. Further research is necessary to evaluate the effectiveness and operational life

expectancies of peat biofilter systems under varying contaminant loading and hydraulic loading rates.

Specific short-term work arising directly from this study would include:

1. Changing the hydraulic loading rate of peat filter columns on a large scale, which could provide more clarity on the impact of clogging.
2. Providing a sedimentation tank after the aeration basin could reduce the suspended solid load on the peat filter, which could significantly increase the life expectancies of peat biofilter columns.
3. Measuring the RedOx potential within the peat filter profile could provide a clearer idea about the aerobic and anaerobic zones, which are the principal requirement for the nitrification and denitrification processes.
4. Bacterial characterization of the peat biofilter could provide a clearer understanding of the impact of clogging as a result of microbial growth during operation.
5. Monitoring the moisture content within the peat column profile could provide a more accurate idea about the changing of the coefficient of unsaturated hydraulic conductivity over time.

Long-term study would consider the following.

1. Emphasis should be provided for proper design of aeration basin geometry, diffuser type, diffuser submergence, diffuser density, and placement of the diffusers in the case of pilot-scale and full-scale systems.

2. Field-scale investigation of the effect that temperature could have on the performance of the peat filter for the removal of contaminants, as well as on clogging should be evaluated.
3. Determination of the best disposal strategies for spent peat, and the sludge resulting from aeration tank, should also be considered further.

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APPENDIX A
PROPERTIES OF PEAT

Table A-1: Particle Size Range of Peat Columns (5-day HRT & 2-day HRT)

EXPERIMENTAL PROCEDURE			
Determined the weights of three empty buckets Sieved peat with No. 8 mesh; placed the fraction retained on No. 8 sieve into one empty buckets Sieved fraction through No.8 mesh with No.16 sieve; placed the fraction retained and through in other two buckets Weighed the three bucket with peat samples Calculated the Particle Size Range of the peat sample			
THEORY/RATIONALE			
Coarse fiber = Fraction retained on No. 8 mesh Medium fiber = Fraction retained on No. 16 mesh Fine fibers and fines = Fraction through No. 16 mesh			
REFERENCES			
ASTM Standard D2977-71: Standard Test Method for Particle Size Range of Peat Materials for Horticultural Purposes Laboratory Methods for Testing Peat Ontario Peatland Inventory Project: Ontario Geological Survey Misc. Paper 145			
NOTES			
All sieved were US Standard sieve Opening of No.8 mesh = 2.36mm No. 16 (1.18mm) sieve was used instead of No. 20 (0.85mm) sieve			
5-DAY HRT and 2-DAY HRT:			
	Fraction retained on No. 8 Sieve	Fraction Through No. 8 Sieve	Fraction through No.16 Sieve
Weight of Bucket (kg)	0.505	0.905	0.995
Weight of Peat + Bucket (kg)	2.44	3.54	6.49
Weight of Peat (kg)	1.935	2.635	5.495
% of Peat	19.22	26.18	54.60
Peat Source	Fiber Size (%)		
	Coarse	Medium	Fine
Alfred, Ontario	19.22	26.18	54.60

Table A-2: Moisture Content of Peat Columns (5-day HRT & 2-day HRT)

EXPERIMENTAL PROCEDURE				
Mixed uniformly of sieved peat Weighed the three empty crucible Weighed the crucibles with as-received peat samples; dried in oven at 105° C for 24 hours Weighed the oven dried samples with crucibles Determined the moisture content as-received mass basis.				
THEORY/RATIONALE				
REFERENCES				
ASTM Standard D 2974-87: Standard Test Method for Moisture, Ash, and Organic Matter of Peat and Other Organic Laboratory Methods for Testing Peat Ontario Peatland Inventory Project: Ontario Geological Survey Misc. Paper 145				
NOTES				
Moisture content as a percentage of as-received mass basis				
5-DAY HRT:				
Crucible No.	Crucible Wt.(g)	Wt. of as-received peat + Crucible (g)	Wt. of oven dry peat + Crucible (g)	Moisture content as received mass basis (%)
A1	55.1753	61.4875	57.5888	61.76
A2	56.3021	61.8136	58.4173	61.62
A3	56.6944	66.1418	63.3319	29.74
			Average	51.04
			Std. Dev.	18.45
2-DAY HRT:				
Crucible No.	Crucible Wt.(g)	Wt. of as-received peat + Crucible (g)	Wt. of oven dry peat + Crucible (g)	Moisture content as received mass basis (%)
A1	30.4692	50.2238	47.4334	14.13
A2	30.7913	50.2661	47.4797	14.31
A3	30.3276	51.3477	48.3625	14.20
			Average	14.21
			Std. Dev.	0.09

Table A-3: Ash and Organic Matter Content of Peat Columns (5-day & 2-day HRT)

EXPERIMENTAL PROCEDURE					
Placed oven-dried samples in muffle furnace and heated to 440° C for a 2 hour period					
Weighed the ash with crucible					
Determined ash and organic matter content					
THEORY/RATIONALE					
Ash content reported on oven-dried mass basis					
REFERENCES					
ASTM Standard D 2974-87: Standard Test Method for Moisture, Ash, and Organic Matter of Peat and Other Organic					
Laboratory Methods for Testing Peat Ontario Peatland Inventory Project: Ontario Geological Survey Misc. Paper 145					
NOTES					
5-DAY HRT:					
Crucible No.	Crucible Wt.(g)	Wt. of oven dry peat + Crucible (g)	Wt. of Ash + Crucible (g)	Ash Content (%)	Organic Matter Content (%)
A1	55.1753	57.5888	55.4663	12.06	87.94
A2	56.3021	58.4173	56.556	12.00	88.00
A3	56.6944	63.3319	57.1799	7.31	92.69
Average				10.46	89.54
Std. Dev.				2.72	2.72
2-DAY HRT:					
Crucible No.	Crucible Wt.(g)	Wt. of oven dry peat + Crucible (g)	Wt. of Ash + Crucible (g)	Ash Content (%)	Organic Matter Content (%)
A1	30.4692	47.4334	33.2365	16.31	83.69
A2	30.7913	47.4797	34.1298	20.00	80.00
A3	30.3276	48.3625	32.1563	10.14	89.86
Average				15.49	84.51
Std. Dev.				4.98	4.98

Table A-4: Bulk Density of Peat Columns (5-day HRT & 2-day HRT)

EXPERIMENTAL PROCEDURE							
Mixed uniformly of sieved peat; Determined moisture content of peat Weighed empty columns; Compacted columns to desire depth Weighed columns + air-dried peat; Record column ID, area and height of peat Computed bulk density							
THEORY/RATIONALE							
REFERENCES							
ASTM Standard D 4531-86: Standard Test Method for Bulk Density of Peat and Peat Products Laboratory Methods for Testing Peat Ontario Peatland Inventory Project: Ontario Geological Survey Misc. Paper 145							
NOTES							
Moisture Content = 51.04 % for 5-day HRT, and =14.21 % for 2-day HRT							
5-DAY HRT:		Average 8.28 cm³/cm²/day HLR			Average 10.82 cm³/cm²/day HLR		
Parameters	Distilled Water Col.	Column 1	Column 2	Column 3	Column 1	Column 2	Column 3
Column Weight (kg)	2.100	2.100	1.635	2.030	1.925	1.770	2.125
Peat +Col. Wt. (kg)	2.760	3.075	2.445	3.005	2.945	2.545	3.095
Net Wt. of Peat (kg)	0.660	0.975	0.810	0.975	1.020	0.775	0.970
Area of column (cm ²)	90.425	81.713	81.073	81.713	82.355	80.914	81.073
Height of Peat Col. (cm)	25.250	23.300	21.730	24.010	24.160	21.640	22.820
Volume of column (m ³)	0.0023	0.0019	0.0018	0.0020	0.0020	0.0018	0.0019
Bulk Density (kg/m ³)	289.06	512.10	459.78	496.96	512.64	442.61	524.30
2-DAY HRT:		Average 8.28 cm³/cm²/day HLR			Average 10.82 cm³/cm²/day HLR		
Parameters	Distilled Water Col.	Column 1	Column 2	Column 3	Column 1	Column 2	Column 3
Column Weight (kg)	-	-	-	-	-	-	-
Peat +Col. Wt. (kg)	-	-	-	-	-	-	-
Net Wt. of Peat (kg)	0.850	0.850	0.850	0.850	0.850	0.850	0.850
Area of column (cm ²)	90.425	81.713	81.073	81.713	82.355	80.914	81.073
Height of Peat Col. (cm)	21.450	24.700	24.350	24.010	24.350	25.750	25.480
Volume of column (m ³)	0.0019	0.0020	0.0020	0.0020	0.0020	0.0021	0.0021
Bulk Density (kg/m ³)	438.23	421.14	430.57	433.25	423.87	407.96	411.47

Table A-5: Corrected Hydraulic Conductivity of Column

HYDRAULIC CONDUCTIVITY OF COLUMNS TEMPERATURE CORRECTION					
THEORY/RATIONALE					
$k_{20} = k_T \left(\frac{\mu_T}{\mu_{20}} \right)$ <p>Where, k_{20} is the hydraulic conductivity at 20° C, whereas k_T is the hydraulic conductivity at T° C. μ_T is viscosity of water at T° C, and μ_{20} is viscosity of water at 20° C.</p>					
REFERENCES					
ASTM Standard D 4511-92: Standard Test Method for Hydraulic Conductivity of Essentially Saturated Peat (Constant Head)					
Tchobanoglous, G., Burton, F.L.; 1991; APPENDIX C in <i>Wastewater Engineering: Treatment, Disposal and Reuse</i> (Metcalf & Eddy, Inc.); 3 rd edition; McGraw-Hill, Inc.; New York.					
NOTES					
$\mu_{20}=1.002 \times 10^{-3} \text{ N.s/m}^2$					
5-DAY HRT & 2-DAY HRT:					
Column ID		Temperature ° C		Viscosity, $\mu_T \times 10^{-3} \text{ (N.s/m}^2\text{)}$	
		5-day HRT	2-day HRT	5-day HRT	2-day HRT
Avg. 8.28 $\text{cm}^3/\text{cm}^2/\text{day HLR}$	Column 1	8	18.5	1.391	1.043
	Column 2	9	18	1.349	1.057
	Column 3	14	17.5	1.173	1.071
Avg. 10.82 $\text{cm}^3/\text{cm}^2/\text{day HLR}$	Column 1	7	17.5	1.434	1.071
	Column 2	8	18	1.391	1.057
	Column 3	11	17.5	1.273	1.071
Distilled Water	Column DW	11	17.5	1.273	1.071
5-DAY HRT & 2-DAY HRT:					
Column ID		$k_T \text{ (cm/s)}$		$k_{20} \text{ (cm/s)}$	
		5-day HRT	2-day HRT	5-day HRT	2-day HRT
Avg. 8.28 $\text{cm}^3/\text{cm}^2/\text{day HLR}$	Column 1	0.006069	0.005460	0.008425	0.005683
	Column 2	0.003786	0.004974	0.005097	0.005247
	Column 3	0.006509	0.003498	0.007620	0.003739
Avg. 10.82 $\text{cm}^3/\text{cm}^2/\text{day HLR}$	Column 1	0.015353	0.008944	0.021972	0.009560
	Column 2	0.011701	0.010372	0.016244	0.010941
	Column 3	0.019131	0.015029	0.024305	0.016064
Distilled Water	Column DW	0.023512	0.013547	0.029871	0.014480

Table A-6: Hydraulic Conductivity (Column 1, Avg. 8.28 cm³/cm²/day HLR, 5-day HRT)

EXPERIMENTAL PROCEDURE										
Mixed uniformly of sieved peat; Determined moisture content of peat										
Weighed Columns; Packed columns; Weighed columns + air-dried peat; Record ID, area and length of peat										
Flooded columns using constant head apparatus for 24 hours; Flow in = flow out										
For a constant head of 47.25 cm, collected water samples at 1 minute intervals in pre-weighed set of bottles										
Recorded weight of beaker and water; Determined weight of water; Computed cumulative volume of water collected over time										
Plotted cumulative volume of water Vs. time and calculated flow rate; Computed hydraulic conductivity										
Repeated procedure for constant heads of 62.25cm and 32.25cm; Calculated average hydraulic conductivity										
Calculated hydraulic conductivity for temperature correction										
THEORY/RATIONALE										
Assume 1 g of water = 1 cm ³ of water										
REFERENCES										
ASTM Standard D 4511-92: Standard Test Method for Hydraulic Conductivity of Essentially Saturated Peat (Constant Head)										
Laboratory Methods for Testing Peat Ontario Peatland Inventory Project: Ontario Geological Survey Misc. Paper 145										
NOTES										
Bulk Density = 512.10 kg/m ³										
Moisture Content = 51.04 %										
Water Temperature = 8° C										
Temperature correction for 20° C										
Time (min)	Bottle Weight (g)	Bott. + H ₂ O Weight (1) (g)	H ₂ O(1) Weight (g)	Cum. H ₂ O (1) Vol (cm ³)	Bott. + H ₂ O Weight (2) (g)	H ₂ O(2) Weight (g)	Cum. H ₂ O (2) Vol (cm ³)	Bott. + H ₂ O Weight (3) (g)	H ₂ O(3) Weight (g)	Cum. H ₂ O (3) Vol (cm ³)
1	75.26	139.2	63.91	63.91	168.2	92.89	92.89	106.1	30.87	30.87
2	75.08	139	63.89	127.8	168	92.95	185.8	106.1	31.03	61.9
3	75.15	139.1	63.91	191.7	168	92.86	278.7	106.7	31.53	93.43
4	75.18	139.1	63.88	255.6	168.5	93.29	372	105.9	30.67	124.1
5	75.51	139.4	63.93	319.5	168.5	93.02	465	106.4	30.89	155
6	75.23	139.2	63.92	383.4	169.1	93.85	558.9	106	30.79	185.8
7	75.39	139.3	63.95	447.4	168.5	93.13	652	106.7	31.29	217.1
8	75.39	139.3	63.89	511.3	168.8	93.41	745.4	107	31.59	248.7
9	75.57	139.5	63.96	575.2	169.6	94.03	839.4	107.3	31.68	280.3
10	75.19	139.1	63.87	639.1	169.3	94.12	933.6	107.3	32.06	312.4
11	75.05	138.9	63.88	703	169.3	94.21	1028	107.3	32.27	344.7
12	75.03	138.9	63.85	766.8	169	93.96	1122	107.1	32.08	376.8
13	75.01	138.9	63.87	830.7	168.3	93.26	1215	106.6	31.63	408.4
14	74.96	138.9	63.89	894.6	168.5	93.57	1309	105.8	30.87	439.3
15	74.95	138.8	63.89	958.5	169.1	94.19	1403	105.2	30.29	469.5
ID(cm)	L(cm)	Q/t (cm ³ /min)	k ₍₁₎ (cm/s)		Q/t (cm ³ /min)	k ₍₂₎ (cm/s)		Q/t (cm ³ /min)	k ₍₃₎ (cm/s)	
10.20	23.30	63.90	0.006427		93.61	0.007147		31.45	0.004635	
A(cm ²)	k _T (cm/s)	H(cm)			H(cm)			H(cm)		
81.713	0.006069	47.25			62.25			32.25		

Table A-7: Hydraulic Conductivity (Column 2, Avg. 8.28 cm³/cm²/day HLR, 5-day HRT)

EXPERIMENTAL PROCEDURE										
Mixed uniformly of sieved peat; Determined moisture content of peat										
Weighed Columns; Packed columns; Weighed columns + air-dried peat; Record ID, area and length of peat										
Flooded columns using constant head apparatus for 24 hours; Flow in = flow out										
For a constant head of 47.25 cm, collected water samples at 1 minute intervals in pre-weighed set of bottles										
Recorded weight of beaker and water; Determined weight of water; Computed cumulative volume of water collected over time										
Plotted cumulative volume of water Vs. time and calculated flow rate; Computed hydraulic conductivity										
Repeated procedure for constant heads of 62.25cm and 32.25cm; Calculated average hydraulic conductivity										
Calculated hydraulic conductivity for temperature correction										
THEORY/RATIONALE										
Assume 1 g of water = 1 cm ³ of water										
REFERENCES										
ASTM Standard D 4511-92: Standard Test Method for Hydraulic Conductivity of Essentially Saturated Peat (Constant Head)										
Laboratory Methods for Testing Peat Ontario Peatland Inventory Project: Ontario Geological Survey Misc. Paper 145										
NOTES										
Bulk Density = 459.78 kg/m ³										
Moisture Content = 51.04 %										
Water Temperature = 9° C										
Temperature correction for 20° C										
Time (min)	Bottle Weight (g)	Bott. + H ₂ O Weight (g)	H ₂ O(1) Weight (g)	Cum. H ₂ O (1) Vol (cm ³)	Bott. + H ₂ O Weight (2) (g)	H ₂ O(2) Weight (g)	Cum. H ₂ O (2) Vol (cm ³)	Bott. + H ₂ O Weight (3) (g)	H ₂ O(3) Weight (g)	Cum. H ₂ O (3) Vol (cm ³)
1	75.26	108.38	33.12	33.12	131.67	56.41	56.41	106.13	30.87	30.87
2	75.08	108.34	33.26	66.38	131.76	56.68	113.09	106.11	31.03	61.9
3	75.15	108.79	33.64	100.02	131.18	56.03	169.12	106.68	31.53	93.43
4	75.18	108.13	32.95	132.97	131.16	55.98	225.1	105.85	30.67	124.1
5	75.51	108.07	32.56	165.53	131.01	55.5	280.6	106.4	30.89	154.99
6	75.23	107.87	32.64	198.17	132.21	56.98	337.58	106.02	30.79	185.78
7	75.39	109.26	33.87	232.04	132.01	56.62	394.2	105.65	30.26	216.04
8	75.39	108.47	33.08	265.12	131.41	56.02	450.22	105.48	30.09	246.13
9	75.57	108.73	33.16	298.28	131.81	56.24	506.46	105.68	30.11	276.24
10	75.19	107.92	32.73	331.01	131.87	56.68	563.14	105.17	29.98	306.22
11	75.05	108.06	33.01	364.02	130.92	55.87	619.01	104.74	29.69	335.91
12	75.03	107.39	32.36	396.38	130.62	55.59	674.6	105.02	29.99	365.9
13	75.01	107.99	32.98	429.36	131.89	56.88	731.48	105.16	30.15	396.05
14	74.96	107.84	32.88	462.24	131.99	57.03	788.51	105.12	30.16	426.21
15	74.95	107.64	32.69	494.93	132.08	57.13	845.64	105.19	30.24	456.45
ID(cm)	L(cm)	Q/t (cm ³ /min)	k ₁ (cm/s)		Q/t (cm ³ /min)	k ₂ (cm/s)		Q/t (cm ³ /min)	k ₃ (cm/s)	
10.16	21.73	32.98	0.003118		56.31	0.004041		30.32	0.004200	
A(cm ²)	k ₁ (cm/s)	H(cm)			H(cm)			H(cm)		
81.073	0.003786	47.25			62.25			32.25

Figure A-1: Constant Heat Test – Column 1, Avg. $8.28 \text{ cm}^3/\text{cm}^2/\text{day}$ HLR, 5-day HRT

Figure A-2: Constant Heat Test – Column 2, Avg. $8.28 \text{ cm}^3/\text{cm}^2/\text{day}$ HLR, 5-day HRT

Table A-8: Hydraulic Conductivity (Column 3, Avg. 8.28 cm³/cm²/day HLR, 5-day HRT)

EXPERIMENTAL PROCEDURE										
Mixed uniformly of sieved peat; Determined moisture content of peat										
Weighed Columns; Packed columns; Weighed columns + air-dried peat; Record ID, area and length of peat										
Flooded columns using constant head apparatus for 24 hours; Flow in = flow out										
For a constant head of 46.85 cm, collected water samples at 1 minute intervals in pre-weighted set of bottles										
Recorded weight of beaker and water; Determined weight of water; Computed cumulative volume of water collected over time										
Plotted cumulative volume of water Vs. time and calculated flow rate; Computed hydraulic conductivity										
Repeated procedure for constant heads of 62.05cm and 31.95 cm; Calculated average hydraulic conductivity										
Calculated hydraulic conductivity for temperature correction										
THEORY/RATIONALE										
Assume 1 g of water = 1 cm ³ of water										
REFERENCES										
ASTM Standard D 4511-92: Standard Test Method for Hydraulic Conductivity of Essentially Saturated Peat (Constant Head)										
Laboratory Methods for Testing Peat Ontario Peatland Inventory Project: Ontario Geological Survey Misc. Paper 145										
NOTES										
Bulk Density = 496.96 kg/m ³										
Moisture Content = 51.04 %										
Water Temperature = 14° C										
Temperature correction for 20° C										
Time (min)	Bottle Weight (g)	Bott. + H ₂ O Weight (1) (g)	H ₂ O(1) Weight (g)	Cum. H ₂ O (1) Vol (cm ³)	Bott. + H ₂ O Weight (2) (g)	H ₂ O(2) Weight (g)	Cum. H ₂ O (2) Vol (cm ³)	Bott. + H ₂ O Weight (3) (g)	H ₂ O(3) Weight (g)	Cum. H ₂ O (3) Vol (cm ³)
1	75.26	138.54	63.28	63.28	167.02	91.76	91.76	113.02	37.76	37.76
2	75.08	138.44	63.36	126.64	167.23	92.15	183.91	113.16	38.08	75.84
3	75.15	137.61	62.46	189.1	168.01	92.86	276.77	112.96	37.81	113.65
4	75.18	136.29	61.11	250.21	168.21	93.03	369.8	112.85	37.67	151.32
5	75.51	137.42	61.91	312.12	167.58	92.07	461.87	112.65	37.14	188.46
6	75.23	137.76	62.53	374.65	167.8	92.57	554.44	112.49	37.26	225.72
7	75.39	138.86	63.47	438.12	166.98	91.59	646.03	112.39	37	262.72
8	75.39	138.64	63.25	501.37	166.82	91.43	737.46	112.59	37.2	299.92
9	75.57	137.76	62.19	563.56	166.59	91.02	828.48	112.98	37.41	337.33
10	75.19	136.91	61.72	625.28	167.01	91.82	920.3	112.76	37.57	374.9
11	75.05	136.71	61.66	686.94	167.03	91.98	1012.28	112.06	37.01	411.91
12	75.03	138.01	62.98	749.92	167.12	92.09	1104.37	113.01	37.98	449.89
13	75.01	137.91	62.9	812.82	166.96	91.95	1196.32	112.89	37.88	487.77
14	74.96	138.18	63.22	876.04	166.49	91.53	1287.85	112.56	37.6	525.37
15	74.95	138.23	63.28	939.32	166.56	91.61	1379.46	112.78	37.83	563.2
ID(cm)	L(cm)	Q/t (cm ³ /min)	k ₁₁ (cm/s)		Q/t (cm ³ /min)	k ₂₂ (cm/s)		Q/t (cm ³ /min)	k ₃₃ (cm/s)	
10.20	24.01	62.49	0.006532		91.93	0.007255		37.44	0.005739	
A(cm ²)	k _r (cm/s)	H(cm)			H(cm)			H(cm)		
81.713	0.006509	46.85			62.05			31.95		

Table A-9: Hydraulic Conductivity (Column 1, Avg. 10.82cm³/cm²/day HLR, 5-day HRT)

EXPERIMENTAL PROCEDURE										
Mixed uniformly of sieved peat; Determined moisture content of peat										
Weighed Columns; Packed columns; Weighed columns + air-dried peat; Record ID, area and length of peat										
Flooded columns using constant head apparatus for 24 hours; Flow in = flow out										
For a constant head of 47.05 cm, collected water samples at 1 minute intervals in pre-weighed set of bottles										
Recorded weight of beaker and water; Determined weight of water; Computed cumulative volume of water collected over time										
Plotted cumulative volume of water Vs. time and calculated flow rate; Computed hydraulic conductivity										
Repeated procedure for constant heads of 62.15cm and 32.15cm; Calculated average hydraulic conductivity										
Calculated hydraulic conductivity for temperature correction										
THEORY/RATIONALE										
Assume 1 g of water = 1 cm ³ of water										
REFERENCES										
ASTM Standard D 4511-92: Standard Test Method for Hydraulic Conductivity of Essentially Saturated Peat (Constant Head)										
Laboratory Methods for Testing Peat Ontario Peatland Inventory Project: Ontario Geological Survey Misc. Paper 145										
NOTES										
Bulk Density = 512.64 kg/m ³										
Moisture Content = 51.04 %										
Water Temperature = 7° C										
Temperature correction for 20° C										
Time (min)	Bottle Weight (g)	Bott. + H ₂ O Weight (1) (g)	H ₂ O(1) Weight (g)	Cum. H ₂ O (1) Vol (cm ³)	Bott. + H ₂ O Weight (2) (g)	H ₂ O(2) Weight (g)	Cum. H ₂ O (2) Vol (cm ³)	Bott. + H ₂ O Weight (3) (g)	H ₂ O(3) Weight (g)	Cum. H ₂ O (3) Vol (cm ³)
1	75.26	203.19	127.93	127.93	184.06	108.8	108.8	277.41	202.15	202.15
2	75.08	201.61	126.53	254.46	186.5	111.42	220.22	279.92	204.84	406.99
3	75.15	204.27	129.12	383.58	185.28	110.13	330.35	278.71	203.56	610.55
4	75.18	203.47	128.29	511.87	185.42	110.24	440.59	282.19	207.01	817.56
5	75.51	204.47	128.96	640.83	184.28	108.77	549.36	283.58	208.07	1025.63
6	75.23	202.9	127.67	768.5	184.7	109.47	658.83	277.76	202.53	1228.16
7	75.39	203.9	128.51	897.01	185.72	110.33	769.16	282.09	206.7	1434.86
8	75.39	202.55	127.16	1024.17	186.84	111.45	880.61	278.6	203.21	1638.07
9	75.57	202.55	126.98	1151.15	182.6	107.03	987.64	280.02	204.45	1842.52
10	75.19	204.61	129.42	1280.57	184.69	109.5	1097.14	279.69	204.5	2047.02
11	75.05	200.86	125.81	1406.38	184.79	109.74	1206.88	280.03	204.98	2252
12	75.03	203.95	128.92	1535.3	182.54	107.51	1314.39	279.67	204.64	2456.64
13	75.01	204.36	129.35	1664.65	185.95	110.94	1425.33	275.49	200.48	2657.12
14	74.96	203.73	128.77	1793.42	183.82	108.86	1534.19	279.19	204.23	2861.35
15	74.95	203.59	128.64	1922.06	185.09	110.14	1644.33	276.21	201.26	3062.61
ID(cm)	L(cm)	Q/t (cm ³ /min)	k ₍₁₎ (cm/s)		Q/t (cm ³ /min)	k ₍₂₎ (cm/s)		Q/t (cm ³ /min)	k ₍₃₎ (cm/s)	
10.24	24.16	128.1	0.013312		109.54	0.016659		204.51	0.016089	
A(cm ²)	k _T (cm/s)	H(cm)			H(cm)			H(cm)		
82.355	0.015353	47.05			32.15			62.15

Figure A-3: Constant Head Test – Column 3, Avg. $8.28\text{ cm}^3/\text{cm}^2/\text{day}$ HLR, 5-day HRT

Figure A-4: Constant Head Test – Column 1, Avg. $10.82\text{ cm}^3/\text{cm}^2/\text{day}$ HLR, 5-day HRT

Table A-10: Hydraulic Conductivity (Column 2, Avg. 10.82 cm³/cm²/day HLR, 5-day HRT)

EXPERIMENTAL PROCEDURE										
Mixed uniformly of sieved peat; Determined moisture content of peat										
Weighed Columns; Packed columns; Weighed columns + air-dried peat; Record ID, area and length of peat										
Flooded columns using constant head apparatus for 24 hours; Flow in = flow out										
For a constant head of 47.25 cm, collected water samples at 1 minute intervals in pre-weighed set of bottles										
Recorded weight of beaker and water; Determined weight of water; Computed cumulative volume of water collected over time										
Plotted cumulative volume of water Vs. time and calculated flow rate; Computed hydraulic conductivity										
Repeated procedure for constant heads of 62.25cm and 32.25cm; Calculated average hydraulic conductivity										
Calculated hydraulic conductivity for temperature correction										
THEORY/RATIONALE										
Assume 1 g of water = 1 cm ³ of water										
REFERENCES										
ASTM Standard D 4511-92: Standard Test Method for Hydraulic Conductivity of Essentially Saturated Peat (Constant Head)										
Laboratory Methods for Testing Peat Ontario Peatland Inventory Project: Ontario Geological Survey Misc. Paper 145										
NOTES										
Bulk Density = 442.61 kg/m ³										
Moisture Content = 51.04 %										
Water Temperature = 8° C										
Temperature correction for 20° C										
Time (min)	Bottle Weight (g)	Bott. + H ₂ O Weight (1) (g)	H ₂ O(1) Weight (g)	Cum. H ₂ O (1) Vol (cm ³)	Bott. + H ₂ O Weight (2) (g)	H ₂ O(2) Weight (g)	Cum. H ₂ O (2) Vol (cm ³)	Bott. + H ₂ O Weight (3) (g)	H ₂ O(3) Weight (g)	Cum. H ₂ O (3) Vol (cm ³)
1	75.26	201.96	126.7	126.7	150.89	75.63	75.63	262.68	187.42	187.42
2	75.08	202.24	127.16	253.86	151.84	76.76	152.39	260.7	185.62	373.04
3	75.15	202.71	127.56	381.42	150.16	75.01	227.4	261.32	186.17	559.21
4	75.18	201.4	126.22	507.64	150.54	75.36	302.76	259.09	183.91	743.12
5	75.51	202.74	127.23	634.87	150.36	74.85	377.61	259.9	184.39	927.51
6	75.23	202.86	127.63	762.5	149.58	74.35	451.96	258.28	183.05	1110.56
7	75.39	202.59	127.2	889.7	149.1	73.71	525.67	258.52	183.13	1293.69
8	75.39	200.82	125.43	1015.13	148.97	73.58	599.25	259.93	184.54	1478.23
9	75.57	199.57	124	1139.13	149.18	73.61	672.86	252.88	177.31	1655.54
10	75.19	198.89	123.7	1262.83	147.56	72.37	745.23	252.29	177.1	1832.64
11	75.05	204.39	129.34	1392.17	147.07	72.02	817.25	255.28	180.23	2012.87
12	75.03	202.47	127.44	1519.61	146.72	71.69	888.94	254.85	179.82	2192.69
13	75.01	207.1	132.09	1651.7	145.77	70.76	959.7	253.68	178.67	2371.36
14	74.96	205.79	130.83	1782.53	145.31	70.35	1030.05	254.68	179.72	2551.08
15	74.95	205.18	130.23	1912.76	145.87	70.92	1100.97	254.91	179.96	2731.04
ID(cm)	L(cm)	Q/t (cm ³ /min)	k ₍₁₎ (cm/s)		Q/t (cm ³ /min)	k ₍₂₎ (cm/s)		Q/t (cm ³ /min)	k ₍₃₎ (cm/s)	
10.15	21.64	127.13	0.011993		73.22	0.010120		181.41	0.012990	
A(cm ²)	k ₁ (cm/s)	H(cm)			H(cm)			H(cm)		
80.914	0.011701	47.25			32.25			62.25		

Table A-11: Hydraulic Conductivity (Column 3, Avg. 10.82 cm³/cm²/day HLR, 5-day HRT)

EXPERIMENTAL PROCEDURE										
Mixed uniformly of sieved peat; Determined moisture content of peat										
Weighed Columns; Packed columns; Weighed columns + air-dried peat; Record ID, area and length of peat										
Flooded columns using constant head apparatus for 24 hours; Flow in = flow out										
For a constant head of 46.75 cm, collected water samples at 1 minute intervals in pre-weighed set of bottles										
Recorded weight of beaker and water; Determined weight of water; Computed cumulative volume of water collected over time										
Plotted cumulative volume of water Vs. time and calculated flow rate; Computed hydraulic conductivity										
Repeated procedure for constant heads of 61.95 cm and 32.05 cm; Calculated average hydraulic conductivity										
Calculated hydraulic conductivity for temperature correction										
THEORY/RATIONALE										
Assume 1 g of water = 1 cm ³ of water										
REFERENCES										
ASTM Standard D 4511-92: Standard Test Method for Hydraulic Conductivity of Essentially Saturated Peat (Constant Head)										
Laboratory Methods for Testing Peat Ontario Peatland Inventory Project: Ontario Geological Survey Misc. Paper 145										
NOTES										
Bulk Density = 524.30 kg/m ³										
Moisture Content = 51.04 %										
Water Temperature = 11° C										
Temperature correction for 20° C										
Time (min)	Bottle Weight (g)	Bott. + H ₂ O Weight (1) (g)	H ₂ O(1) Weight (g)	Cum. H ₂ O (1) Vol (cm ³)	Bott. + H ₂ O Weight (2) (g)	H ₂ O(2) Weight (g)	Cum. H ₂ O (2) Vol (cm ³)	Bott. + H ₂ O Weight (3) (g)	H ₂ O(3) Weight (g)	Cum. H ₂ O (3) Vol (cm ³)
1	75.26	273.92	198.66	198.66	201.36	126.1	126.1	328.51	253.25	253.25
2	75.08	272.19	197.11	395.77	201.17	126.09	252.19	329.31	254.23	507.48
3	75.15	274.44	199.29	595.06	198.14	122.99	375.18	328.32	253.17	760.65
4	75.18	274.23	199.05	794.11	199.85	124.67	499.85	329.01	253.83	1014.48
5	75.51	271.85	196.34	990.45	200.69	125.18	625.03	329.12	253.61	1268.09
6	75.23	271.36	196.13	1186.58	201.58	126.35	751.38	329.26	254.03	1522.12
7	75.39	274.38	198.99	1385.57	201.85	126.46	877.84	328.96	253.57	1775.69
8	75.39	272.04	196.65	1582.22	201.69	126.3	1004.14	329.02	253.63	2029.32
9	75.57	270.58	195.01	1777.23	201.57	126	1130.14	328.96	253.39	2282.71
10	75.19	269.98	194.79	1972.02	201.62	126.43	1256.57	328.65	253.46	2536.17
11	75.05	270.95	195.9	2167.92	201.61	126.56	1383.13	329.68	254.63	2790.8
12	75.03	269.96	194.93	2362.85	201.95	126.92	1510.05	329.74	254.71	3045.51
13	75.01	270.59	195.58	2558.43	201.43	126.42	1636.47	329.61	254.6	3300.11
14	74.96	271.68	196.72	2755.15	201.31	126.35	1762.82	329.38	254.42	3554.53
15	74.95	271.96	197.01	2952.16	201.67	126.72	1889.54	329.62	254.67	3809.2
HD(cm)	L(cm)	Q/t (cm ³ /min)	k ₁₁ (cm/s)		Q/t (cm ³ /min)	k ₂₂ (cm/s)		Q/t (cm ³ /min)	k ₃₃ (cm/s)	
10.16	22.82	196.49	0.019717		126.04	0.018449		253.92	0.019228	
A(cm ²)	k ₁ (cm/s)	H(cm)			H(cm)			H(cm)		
81.073	0.019131	46.75			32.05			61.95

Figure A-5: Constant Head Test – Column 2, Avg. $10.82 \text{ cm}^3/\text{cm}^2/\text{day}$ HLR, 5-day HRT

Figure A-6: Constant Head Test – Column 3, Avg. $10.82 \text{ cm}^3/\text{cm}^2/\text{day}$ HLR, 5-day HRT

Table A-12: Hydraulic Conductivity (ColumnDW, Avg.10.82cm³/cm²/dayHLR, 5-day HRT)

EXPERIMENTAL PROCEDURE										
Mixed uniformly of sieved peat; Determined moisture content of peat										
Weighed Columns; Packed columns; Weighed columns + air-dried peat; Record ID, area and length of peat										
Flooded columns using constant head apparatus for 24 hours; Flow in = flow out										
For a constant head of 57.75 cm, collected water samples at 1 minute intervals in pre-weighted set of bottles										
Recorded weight of beaker and water; Determined weight of water; Computed cumulative volume of water collected over time										
Plotted cumulative volume of water Vs. time and calculated flow rate; Computed hydraulic conductivity										
Repeated procedure for constant heads of 72.25cm and 32.35cm; Calculated average hydraulic conductivity										
Calculated hydraulic conductivity for temperature correction										
THEORY/RATIONALE										
Assume 1 g of water = 1 cm ³ of water										
REFERENCES										
ASTM Standard D 4511-92: Standard Test Method for Hydraulic Conductivity of Essentially Saturated Peat (Constant Head)										
Laboratory Methods for Testing Peat Ontario Peatland Inventory Project: Ontario Geological Survey Misc. Paper 145										
NOTES										
Bulk Density = 289.06 kg/m ³										
Moisture Content = 51.04 %										
Water Temperature = 11° C										
Temperature correction for 20° C										
Time (min)	Bottle Weight (g)	Bott. + H ₂ O Weight (1) (g)	H ₂ O(1) Weight (g)	Cum. H ₂ O (1) Vol (cm ³)	Bott. + H ₂ O Weight (2) (g)	H ₂ O(2) Weight (g)	Cum. H ₂ O (2) Vol (cm ³)	Bott. + H ₂ O Weight (3) (g)	H ₂ O(3) Weight (g)	Cum. H ₂ O (3) Vol (cm ³)
1	75.26	368.66	293.4	293.4	238.61	163.35	163.35	438.53	363.27	363.27
2	75.08	368.62	293.54	586.94	238.53	163.45	326.8	438.52	363.44	726.71
3	75.15	368.32	293.17	880.11	238.42	163.27	490.07	438.69	363.54	1090.25
4	75.18	368.32	293.14	1173.25	238.59	163.41	653.48	438.29	363.11	1453.36
5	75.51	368.92	293.41	1466.66	238.26	162.75	816.23	438.51	363	1816.36
6	75.23	368.15	292.92	1759.58	238.24	163.01	979.24	438.62	363.39	2179.75
7	75.39	368.95	293.56	2053.14	238.75	163.36	1142.6	438.69	363.3	2543.05
8	75.39	368.75	293.36	2346.5	238.95	163.56	1306.16	438.57	363.18	2906.23
9	75.57	368.45	292.88	2639.38	238.68	163.11	1469.27	438.47	362.9	3269.13
10	75.19	368.43	293.24	2932.62	238.59	163.4	1632.67	438.49	363.3	3632.43
11	75.05	368.62	293.57	3226.19	238.57	163.52	1796.19	438.62	363.57	3996
12	75.03	368.53	293.5	3519.69	238.47	163.44	1959.63	438.72	363.69	4359.69
13	75.01	368.51	293.5	3813.19	238.59	163.58	2123.21	438.51	363.5	4723.19
14	74.96	368.57	293.61	4106.8	238.43	163.47	2286.68	438.26	363.3	5086.49
15	74.95	368.59	293.64	4400.44	238.47	163.52	2450.2	438.61	363.66	5450.15
ID(cm)	L(cm)	Q/t (cm ³ /min)	k ₍₁₎ (cm/s)		Q/t (cm ³ /min)	k ₍₂₎ (cm/s)		Q/t (cm ³ /min)	k ₍₃₎ (cm/s)	
10.73	25.25	293.32	0.023638		163.32	0.023496		363.31	0.023402	
A(cm ²)	k ₁ (cm/s)	H(cm)			H(cm)			H(cm)		
90.425	0.023512	57.75			32.35			72.25

Figure A-7: Constant Head Test – Column DW, Avg. $10.82 \text{ cm}^3/\text{cm}^2/\text{day}$ HLR, 5-day HRT

Table A-13: Hydraulic Conductivity (Column 1, Avg. 8.28cm³/cm²/day HLR, 2-day HRT)

EXPERIMENTAL PROCEDURE										
Mixed uniformly of sieved peat; Determined moisture content of peat										
Weighed Columns; Packed columns; Weighed columns + air-dried peat; Record ID, area and length of peat										
Flooded columns using constant head apparatus for 24 hours; Flow in = flow out										
For a constant head of 47.05 cm, collected water samples at 1 minute intervals in pre-weighed set of bottles										
Recorded weight of beaker and water; Determined weight of water; Computed cumulative volume of water collected over time										
Plotted cumulative volume of water Vs. time and calculated flow rate; Computed hydraulic conductivity										
Repeated procedure for constant heads of 62.25cm and 32.05cm; Calculated average hydraulic conductivity										
Calculated hydraulic conductivity for temperature correction										
THEORY/RATIONALE										
Assume 1 g of water = 1 cm ³ of water										
REFERENCES										
ASTM Standard D 4511-92: Standard Test Method for Hydraulic Conductivity of Essentially Saturated Peat (Constant Head)										
Laboratory Methods for Testing Peat Ontario Peatland Inventory Project: Ontario Geological Survey Misc. Paper 145										
NOTES										
Bulk Density = 421.14 kg/m ³										
Moisture Content = 14.21 %										
Water Temperature = 18.5° C										
Temperature correction for 20° C										
Time (min)	Bottle Weight (g)	Bott. + H ₂ O Weight (1) (g)	H ₂ O(1) Weight (g)	Cum. H ₂ O (1) Vol (cm ³)	Bott. + H ₂ O Weight (2) (g)	H ₂ O(2) Weight (g)	Cum. H ₂ O (2) Vol (cm ³)	Bott. + H ₂ O Weight (3) (g)	H ₂ O(3) Weight (g)	Cum. H ₂ O (3) Vol (cm ³)
1	75.26	126.05	50.79	50.79	110.89	35.63	35.63	140.65	65.39	65.39
2	75.08	126.12	51.04	101.83	110.26	35.18	70.81	140.6	65.52	130.91
3	75.15	126.21	51.06	152.89	110.59	35.44	106.25	140.61	65.46	196.37
4	75.18	126.08	50.9	203.79	110.64	35.46	141.71	140.56	65.38	261.75
5	75.51	126.11	50.6	254.39	110.81	35.3	177.01	140.63	65.12	326.87
6	75.23	126.66	51.43	305.82	111.06	35.83	212.84	141.26	66.03	392.9
7	75.39	126.6	51.21	357.03	111.02	35.63	248.47	141.02	65.63	458.53
8	75.39	126.59	51.2	408.23	111.08	35.69	284.16	141.32	65.93	524.46
9	75.57	126.65	51.08	459.31	110.98	35.41	319.57	141.51	65.94	590.4
10	75.19	126.61	51.42	510.73	110.95	35.76	355.33	141.02	65.83	656.23
11	75.05	125.51	50.46	561.19	111.03	35.98	391.31	141.14	66.09	722.32
12	75.03	125.57	50.54	611.73	110.44	35.41	426.72	141.15	66.12	788.44
13	75.01	125.98	50.97	662.7	110.45	35.44	462.16	141.2	66.19	854.63
14	74.96	125.64	50.68	713.38	110.49	35.53	497.69	141.06	66.1	920.73
15	74.95	125.89	50.94	764.32	110.51	35.56	533.25	141.09	66.14	986.87
ID(cm)	L(cm)	Q/t (cm ³ /min)	k ₍₁₎ (cm/s)		Q/t (cm ³ /min)	k ₍₂₎ (cm/s)		Q/t (cm ³ /min)	k ₍₃₎ (cm/s)	
10.20	24.70	50.99	0.005460		35.58	0.005593		65.83	0.005328	
A(cm ²)	k _r (cm/s)	H(cm)			H(cm)			H(cm)		
81.713	0.005460	47.05			32.05			62.25		

Table A-14: Hydraulic Conductivity (Column 2, Avg. 8.28cm³/cm²/day HLR, 2-day HRT)

EXPERIMENTAL PROCEDURE										
Mixed uniformly of sieved peat; Determined moisture content of peat										
Weighed Columns; Packed columns; Weighed columns + air-dried peat; Record ID, area and length of peat										
Flooded columns using constant head apparatus for 24 hours; Flow in = flow out										
For a constant head of 47.35 cm, collected water samples at 1 minute intervals in pre-weighed set of bottles										
Recorded weight of beaker and water; Determined weight of water; Computed cumulative volume of water collected over time										
Plotted cumulative volume of water Vs. time and calculated flow rate; Computed hydraulic conductivity										
Repeated procedure for constant heads of 62.45cm and 32.25cm; Calculated average hydraulic conductivity										
Calculated hydraulic conductivity for temperature correction										
THEORY/RATIONALE										
Assume 1 g of water = 1 cm ³ of water										
REFERENCES										
ASTM Standard D 4511-92: Standard Test Method for Hydraulic Conductivity of Essentially Saturated Peat (Constant Head)										
Laboratory Methods for Testing Peat Ontario Peatland Inventory Project: Ontario Geological Survey Misc. Paper 145										
NOTES										
Bulk Density = 430.57 kg/m ³										
Moisture Content = 14.21 %										
Water Temperature = 18 ° C										
Temperature correction for 20° C										
Time (min)	Bottle Weight (g)	Bott. + H ₂ O Weight (1) (g)	H ₂ O(1) Weight (g)	Cum. H ₂ O (1) Vol (cm ³)	Bott. + H ₂ O Weight (2) (g)	H ₂ O(2) Weight (g)	Cum. H ₂ O (2) Vol (cm ³)	Bott. + H ₂ O Weight (3) (g)	H ₂ O(3) Weight (g)	Cum. H ₂ O (3) Vol (cm ³)
1	75.26	123.49	48.23	48.23	108.13	32.87	32.87	134.89	59.63	59.63
2	75.08	123.51	48.43	96.66	108.36	33.28	66.15	134.87	59.79	119.42
3	75.15	122.95	47.8	144.46	108.51	33.36	99.51	134.59	59.44	178.86
4	75.18	122.98	47.8	192.26	108.21	33.03	132.54	134.23	59.05	237.91
5	75.51	123.02	47.51	239.77	108.14	32.63	165.17	134.61	59.1	297.01
6	75.23	123.61	48.38	288.15	107.89	32.66	197.83	134.52	59.29	356.3
7	75.39	123.59	48.2	336.35	108.01	32.62	230.45	134.92	59.53	415.83
8	75.39	123.41	48.02	384.37	107.69	32.3	262.75	134.61	59.22	475.05
9	75.57	122.89	47.32	431.69	107.83	32.26	295.01	134.59	59.02	534.07
10	75.19	122.79	47.6	479.29	108.12	32.93	327.94	134.87	59.68	593.75
11	75.05	122.96	47.91	527.2	108.11	33.06	361	134.89	59.84	653.59
12	75.03	123.06	48.03	575.23	108.11	33.08	394.08	134.26	59.23	712.82
13	75.01	123.15	48.14	623.37	108.2	33.19	427.27	135.02	60.01	772.83
14	74.96	123.31	48.35	671.72	107.98	33.02	460.29	135.12	60.16	832.99
15	74.95	123.41	48.46	720.18	107.89	32.94	493.23	134.94	59.99	892.98
ID(cm)	L(cm)	Q/t (cm ³ /min)	k ₍₁₎ (cm/s)		Q/t (cm ³ /min)	k ₍₂₎ (cm/s)		Q/t (cm ³ /min)	k ₍₃₎ (cm/s)	
10.16	24.35	47.93	0.005067		32.80	0.005091		59.45	0.004765	
A(cm ²)	k _T (cm/s)	H(cm)			H(cm)			H(cm)		
81.073	0.004974	47.35			32.25			62.45

Figure A-8: Constant Head Test – Column 1, Avg. $8.28 \text{ cm}^3/\text{cm}^2/\text{day}$ HLR, 2-day HRT

Figure A-9: Constant Head Test – Column 2, Avg. $8.28 \text{ cm}^3/\text{cm}^2/\text{day}$ HLR, 2-day HRT

Table A-15: Hydraulic Conductivity (Column 3, Avg. 8.28cm³/cm²/day HLR, 2-day HRT)

EXPERIMENTAL PROCEDURE										
Mixed uniformly of sieved peat; Determined moisture content of peat										
Weighed Columns; Packed columns; Weighed columns + air-dried peat; Record ID, area and length of peat										
Flooded columns using constant head apparatus for 24 hours; Flow in = flow out										
For a constant head of 47.35 cm, collected water samples at 1 minute intervals in pre-weighed set of bottles										
Recorded weight of beaker and water; Determined weight of water; Computed cumulative volume of water collected over time										
Plotted cumulative volume of water Vs. time and calculated flow rate; Computed hydraulic conductivity										
Repeated procedure for constant heads of 62.45cm and 32.25cm; Calculated average hydraulic conductivity										
Calculated hydraulic conductivity for temperature correction										
THEORY/RATIONALE										
Assume 1 g of water = 1 cm ³ of water										
REFERENCES										
ASTM Standard D 4511-92: Standard Test Method for Hydraulic Conductivity of Essentially Saturated Peat (Constant Head)										
Laboratory Methods for Testing Peat Ontario Peatland Inventory Project: Ontario Geological Survey Misc. Paper 145										
NOTES										
Bulk Density = 433.25 kg/m ³										
Moisture Content = 14.21 %										
Water Temperature = 17.5° C										
Temperature correction for 20° C										
Time (min)	Bottle Weight (g)	Bott. + H ₂ O Weight (1) (g)	H ₂ O(1) Weight (g)	Cum. H ₂ O (1) Vol (cm ³)	Bott. + H ₂ O Weight (2) (g)	H ₂ O(2) Weight (g)	Cum. H ₂ O (2) Vol (cm ³)	Bott. + H ₂ O Weight (3) (g)	H ₂ O(3) Weight (g)	Cum. H ₂ O (3) Vol (cm ³)
1	75.26	108.13	32.87	32.87	92.13	16.87	16.87	133.13	57.87	57.87
2	75.08	108.1	33.02	65.89	92.03	16.95	33.82	133.68	58.6	116.47
3	75.15	107.98	32.83	98.72	92.15	17	50.82	133.95	58.8	175.27
4	75.18	108.21	33.03	131.75	92.07	16.89	67.71	133.26	58.08	233.35
5	75.51	108.25	32.74	164.49	91.95	16.44	84.15	133.21	57.7	291.05
6	75.23	107.89	32.66	197.15	91.89	16.66	100.81	133.05	57.82	348.87
7	75.39	107.98	32.59	229.74	92.13	16.74	117.55	133.69	58.3	407.17
8	75.39	107.85	32.46	262.2	92.15	16.76	134.31	133.56	58.17	465.34
9	75.57	108.31	32.74	294.94	92.24	16.67	150.98	133.45	57.88	523.22
10	75.19	108.01	32.82	327.76	92.14	16.95	167.93	133.21	58.02	581.24
11	75.05	108.2	33.15	360.91	91.89	16.84	184.77	132.89	57.84	639.08
12	75.03	108.11	33.08	393.99	91.86	16.83	201.6	132.98	57.95	697.03
13	75.01	107.79	32.78	426.77	91.92	16.91	218.51	132.96	57.95	754.98
14	74.96	107.85	32.89	459.66	91.69	16.73	235.24	133.05	58.09	813.07
15	74.95	108.21	33.26	492.92	92.06	17.11	252.35	133.16	58.21	871.28
ID(cm)	L(cm)	Q/t (cm ³ /min)	k ₁ (cm/s)		Q/t (cm ³ /min)	k ₂ (cm/s)		Q/t (cm ³ /min)	k ₃ (cm/s)	
10.20	24.01	32.81	0.003393		16.79	0.002550		58.04	0.004551	
A(cm ²)	k _T (cm/s)	H(cm)			H(cm)			H(cm)		
81.713	0.003498	47.35			32.25			62.45		

Table A-16: Hydraulic Conductivity (Column 1, Avg. 10.82 cm³/cm²/day HLR, 2-day HRT)

EXPERIMENTAL PROCEDURE										
Mixed uniformly of sieved peat; Determined moisture content of peat										
Weighed Columns; Packed columns; Weighed columns + air-dried peat; Record ID, area and length of peat										
Flooded columns using constant head apparatus for 24 hours; Flow in = flow out										
For a constant head of 47.35 cm, collected water samples at 1 minute intervals in pre-weighed set of bottles										
Recorded weight of beaker and water; Determined weight of water; Computed cumulative volume of water collected over time										
Plotted cumulative volume of water Vs. time and calculated flow rate; Computed hydraulic conductivity										
Repeated procedure for constant heads of 62.65cm and 32.45cm; Calculated average hydraulic conductivity										
Calculated hydraulic conductivity for temperature correction										
THEORY/RATIONALE										
Assume 1 g of water = 1 cm ³ of water										
REFERENCES										
ASTM Standard D 4511-92: Standard Test Method for Hydraulic Conductivity of Essentially Saturated Peat (Constant Head)										
Laboratory Methods for Testing Peat Ontario Peatland Inventory Project: Ontario Geological Survey Misc. Paper 145										
NOTES										
Bulk Density = 423.87 kg/m ³										
Moisture Content = 14.21 %										
Water Temperature = 17.5° C										
Temperature correction for 20° C										
Time (min)	Bottle Weight (g)	Bott. + H ₂ O Weight (1) (g)	H ₂ O(1) Weight (g)	Cum. H ₂ O (1) Vol (cm ³)	Bott. + H ₂ O Weight (2) (g)	H ₂ O(2) Weight (g)	Cum. H ₂ O (2) Vol (cm ³)	Bott. + H ₂ O Weight (3) (g)	H ₂ O(3) Weight (g)	Cum. H ₂ O (3) Vol (cm ³)
1	75.26	161.93	86.67	86.67	135.99	60.73	60.73	185.76	110.5	110.5
2	75.08	161.64	86.56	173.23	135.51	60.43	121.16	185.69	110.61	221.11
3	75.15	162.05	86.9	260.13	135.29	60.14	181.3	185.58	110.43	331.54
4	75.18	161.59	86.41	346.54	135.62	60.44	241.74	185.23	110.05	441.59
5	75.51	161.89	86.38	432.92	135.26	59.75	301.49	185.31	109.8	551.39
6	75.23	161.75	86.52	519.44	135.46	60.23	361.72	185.96	110.73	662.12
7	75.39	161.92	86.53	605.97	135.02	59.63	421.35	185.46	110.07	772.19
8	75.39	161.46	86.07	692.04	135.48	60.09	481.44	185.23	109.84	882.03
9	75.57	161.58	86.01	778.05	135.76	60.19	541.63	185.11	109.54	991.57
10	75.19	162.01	86.82	864.87	135.84	60.65	602.28	185.42	110.23	1101.8
11	75.05	162.1	87.05	951.92	135.02	59.97	662.25	185.64	110.59	1212.39
12	75.03	162.08	87.05	1038.97	135.88	60.85	723.1	185.32	110.29	1322.68
13	75.01	161.77	86.76	1125.73	135.64	60.63	783.73	185.99	110.98	1433.66
14	74.96	161.82	86.86	1212.59	135.49	60.53	844.26	185.94	110.98	1544.64
15	74.95	162.05	87.1	1299.69	135.69	60.74	905	185.23	110.28	1654.92
ID(cm)	L(cm)	Q/t (cm ³ /min)	k ₁ (cm/s)		Q/t (cm ³ /min)	k ₂ (cm/s)		Q/t (cm ³ /min)	k ₃ (cm/s)	
10.24	24.35	86.59	0.009012		60.25	0.009150		110.25	0.008672	
A(cm ²)	k _r (cm/s)	H(cm)			H(cm)			H(cm)		
82.355	0.008944	47.35			32.45			62.65

Figure A-10: Constant Head Test – Column 3, Avg. 8.28 cm³/cm²/day HLR, 2-day HRT

Figure A-11: Constant Head Test – Column 1, Avg. 10.82 cm³/cm²/day HLR, 2-day HRT

Table A-17: Hydraulic Conductivity (Column 2, Avg. 10.82 cm³/cm²/day HLR, 2-day HRT)

EXPERIMENTAL PROCEDURE										
Mixed uniformly of sieved peat; Determined moisture content of peat										
Weighed Columns; Packed columns; Weighed columns + air-dried peat; Record ID, area and length of peat										
Flooded columns using constant head apparatus for 24 hours; Flow in = flow out										
For a constant head of 47.35 cm, collected water samples at 1 minute intervals in pre-weighed set of bottles										
Recorded weight of beaker and water; Determined weight of water; Computed cumulative volume of water collected over time										
Plotted cumulative volume of water Vs. time and calculated flow rate; Computed hydraulic conductivity										
Repeated procedure for constant heads of 62.45 cm and 32.35 cm; Calculated average hydraulic conductivity										
Calculated hydraulic conductivity for temperature correction										
THEORY/RATIONALE										
Assume 1 g of water = 1 cm ³ of water										
REFERENCES										
ASTM Standard D 4511-92: Standard Test Method for Hydraulic Conductivity of Essentially Saturated Peat (Constant Head)										
Laboratory Methods for Testing Peat Ontario Peatland Inventory Project: Ontario Geological Survey Misc. Paper 145										
NOTES										
Bulk Density = 407.96 kg/m ³										
Moisture Content = 14.21 %										
Water Temperature = 18° C										
Temperature correction for 20° C										
Time (min)	Bottle Weight (g)	Bott. + H ₂ O Weight (1) (g)	H ₂ O(1) Weight (g)	Cum. H ₂ O (1) Vol (cm ³)	Bott. + H ₂ O Weight (2) (g)	H ₂ O(2) Weight (g)	Cum. H ₂ O (2) Vol (cm ³)	Bott. + H ₂ O Weight (3) (g)	H ₂ O(3) Weight (g)	Cum. H ₂ O (3) Vol (cm ³)
1	75.26	163.53	88.27	88.27	135.59	60.33	60.33	208.95	133.69	133.69
2	75.08	163.88	88.8	177.07	135.39	60.31	120.64	208.68	133.6	267.29
3	75.15	163.62	88.47	265.54	135.11	59.96	180.6	208.91	133.76	401.05
4	75.18	163.25	88.07	353.61	135.62	60.44	241.04	209.02	133.84	534.89
5	75.51	163.46	87.95	441.56	135.82	60.31	301.35	209.13	133.62	668.51
6	75.23	163.75	88.52	530.08	135.26	60.03	361.38	209	133.77	802.28
7	75.39	163.75	88.36	618.44	135.21	59.82	421.2	208.35	132.96	935.24
8	75.39	163.22	87.83	706.27	135.26	59.87	481.07	208.47	133.08	1068.32
9	75.57	163.55	87.98	794.25	135.4	59.83	540.9	208.69	133.12	1201.44
10	75.19	163.54	88.35	882.6	135.16	59.97	600.87	208.92	133.73	1335.17
11	75.05	163.69	88.64	971.24	135.91	60.86	661.73	209.31	134.26	1469.43
12	75.03	163.26	88.23	1059.47	135.05	60.02	721.75	209.25	134.22	1603.65
13	75.01	163.32	88.31	1147.78	135.64	60.63	782.38	209.16	134.15	1737.8
14	74.96	163.42	88.46	1236.24	135.71	60.75	843.13	210.01	135.05	1872.85
15	74.95	163.65	88.7	1324.94	135.62	60.67	903.8	210.02	135.07	2007.92
ID(cm)	L(cm)	Q/t (cm ³ /min)	k ₁ (cm/s)		Q/t (cm ³ /min)	k ₂ (cm/s)		Q/t (cm ³ /min)	k ₃ (cm/s)	
10.15	25.75	88.28	0.009889		60.18	0.009867		133.74	0.011359	
A(cm ²)	k ₁ (cm/s)	H(cm)			H(cm)			H(cm)		
80.914	0.010372	47.35			32.35			62.45		

Table A-18: Hydraulic Conductivity (Column 3, Avg. 10.82 cm³/cm²/day HLR, 2-day HRT)

EXPERIMENTAL PROCEDURE										
Mixed uniformly of sieved peat; Determined moisture content of peat										
Weighed Columns; Packed columns; Weighed columns + air-dried peat; Record ID, area and length of peat										
Flooded columns using constant head apparatus for 24 hours; Flow in = flow out										
For a constant head of 47.35 cm, collected water samples at 1 minute intervals in pre-weighed set of bottles										
Recorded weight of beaker and water; Determined weight of water; Computed cumulative volume of water collected over time										
Plotted cumulative volume of water Vs. time and calculated flow rate; Computed hydraulic conductivity										
Repeated procedure for constant heads of 62.35cm and 32.35cm; Calculated average hydraulic conductivity										
Calculated hydraulic conductivity for temperature correction										
THEORY/RATIONALE										
Assume 1 g of water = 1 cm ³ of water										
REFERENCES										
ASTM Standard D 4511-92: Standard Test Method for Hydraulic Conductivity of Essentially Saturated Peat (Constant Head)										
Laboratory Methods for Testing Peat Ontario Peatland Inventory Project: Ontario Geological Survey Misc. Paper 145										
NOTES										
Bulk Density = 411.47 kg/m ³										
Moisture Content = 14.21 %										
Water Temperature = 17.5° C										
Temperature correction for 20° C										
Time (min)	Bottle Weight (g)	Bott. + H ₂ O Weight (1) (g)	H ₂ O(1) Weight (g)	Cum. H ₂ O (1) Vol (cm ³)	Bott. + H ₂ O Weight (2) (g)	H ₂ O(2) Weight (g)	Cum. H ₂ O (2) Vol (cm ³)	Bott. + H ₂ O Weight (3) (g)	H ₂ O(3) Weight (g)	Cum. H ₂ O (3) Vol (cm ³)
1	75.26	206.15	130.89	130.89	168.61	93.35	93.35	258.18	182.92	182.92
2	75.08	206.09	131.01	261.9	168.69	93.61	186.96	258.38	183.3	366.22
3	75.15	206.06	130.91	392.81	169.36	94.21	281.17	258.08	182.93	549.15
4	75.18	206.34	131.16	523.97	168.75	93.57	374.74	258.95	183.77	732.92
5	75.51	206.25	130.74	654.71	168.21	92.7	467.44	258.36	182.85	915.77
6	75.23	206.31	131.08	785.79	168.99	93.76	561.2	258.32	183.09	1098.86
7	75.39	206.59	131.2	916.99	168.78	93.39	654.59	258.12	182.73	1281.59
8	75.39	206.54	131.15	1048.14	168.82	93.43	748.02	258.45	183.06	1464.65
9	75.57	206.51	130.94	1179.08	169.12	93.55	841.57	258.65	183.08	1647.73
10	75.19	206.34	131.15	1310.23	169.31	94.12	935.69	258.78	183.59	1831.32
11	75.05	206.16	131.11	1441.34	169.02	93.97	1029.66	258.98	183.93	2015.25
12	75.03	206.45	131.42	1572.76	169.54	94.51	1124.17	258.35	183.32	2198.57
13	75.01	206.82	131.81	1704.57	169.25	94.24	1218.41	258.15	183.14	2381.71
14	74.96	206.49	131.53	1836.1	168.88	93.92	1312.33	258.75	183.79	2565.5
15	74.95	206.74	131.79	1967.89	169.08	94.13	1406.46	258.62	183.67	2749.17
ID(cm)	L(cm)	Q/t (cm ³ /min)	k ₍₁₎ (cm/s)		Q/t (cm ³ /min)	k ₍₂₎ (cm/s)		Q/t (cm ³ /min)	k ₍₃₎ (cm/s)	
10.16	25.48	131.18	0.014512		93.75	0.015180		183.27	0.015397	
A(cm ²)	k ₍₁₎ (cm/s)	H(cm)			H(cm)			H(cm)		
81.073	0.015029	47.35			32.35			62.35

Figure A-12: Constant Head Test – Column 2, Avg. 10.82 cm³/cm²/day HLR, 2-day HRT

Figure A-13: Constant Head Test – Column 3, Avg. 10.82 cm³/cm²/day HLR, 2-day HRT

Table A-19: Hydraulic Conductivity (Column DW, Avg. $10.82 \text{ cm}^3/\text{cm}^2/\text{day}$ HLR, 2-day HRT)

EXPERIMENTAL PROCEDURE										
Mixed uniformly of sieved peat; Determined moisture content of peat										
Weighed Columns; Packed columns; Weighed columns + air-dried peat; Record ID, area and length of peat										
Flooded columns using constant head apparatus for 24 hours; Flow in = flow out										
For a constant head of 57.15 cm, collected water samples at 1 minute intervals in pre-weighed set of bottles										
Recorded weight of beaker and water; Determined weight of water; Computed cumulative volume of water collected over time										
Plotted cumulative volume of water Vs. time and calculated flow rate; Computed hydraulic conductivity										
Repeated procedure for constant heads of 72.25cm and 32.35cm; Calculated average hydraulic conductivity										
Calculated hydraulic conductivity for temperature correction										
THEORY/RATIONALE										
Assume 1 g of water = 1 cm^3 of water										
REFERENCES										
ASTM Standard D 4511-92: Standard Test Method for Hydraulic Conductivity of Essentially Saturated Peat (Constant Head)										
Laboratory Methods for Testing Peat Ontario Peatland Inventory Project: Ontario Geological Survey Misc. Paper 145										
NOTES										
Bulk Density = 438.23 kg/m^3										
Moisture Content = 14.21 %										
Water Temperature = 17.5° C										
Temperature correction for 20° C										
Time (min)	Bottle Weight (g)	Bott. + H ₂ O Weight (1) (g)	H ₂ O(1) Weight (g)	Cum. H ₂ O (1) Vol (cm ³)	Bott. + H ₂ O Weight (2) (g)	H ₂ O(2) Weight (g)	Cum. H ₂ O (2) Vol (cm ³)	Bott. + H ₂ O Weight (3) (g)	H ₂ O(3) Weight (g)	Cum. H ₂ O (3) Vol (cm ³)
1	75.26	267.45	192.19	192.19	326.93	251.67	251.67	185.97	110.71	110.71
2	75.08	267.99	192.91	385.1	327.06	251.98	503.65	186.06	110.98	221.69
3	75.15	267.85	192.7	577.8	327.41	252.26	755.91	185.89	110.74	332.43
4	75.18	267.53	192.35	770.15	326.12	250.94	1006.85	185.38	110.2	442.63
5	75.51	267.68	192.17	962.32	327.15	251.64	1258.49	185.68	110.17	552.8
6	75.23	267.57	192.34	1154.66	326.98	251.75	1510.24	185.75	110.52	663.32
7	75.39	267.95	192.56	1347.22	327.26	251.87	1762.11	186.09	110.7	774.02
8	75.39	267.75	192.36	1539.58	327.31	251.92	2014.03	186.16	110.77	884.79
9	75.57	267.85	192.28	1731.86	327.16	251.59	2265.62	186.26	110.69	995.48
10	75.19	267.63	192.44	1924.3	326.89	251.7	2517.32	186.07	110.88	1106.36
11	75.05	267.91	192.86	2117.16	326.56	251.51	2768.83	186.04	110.99	1217.35
12	75.03	268.12	193.09	2310.25	327.29	252.26	3021.09	186.21	111.18	1328.53
13	75.01	268.32	193.31	2503.56	327.31	252.3	3273.39	186.13	111.12	1439.65
14	74.96	268.14	193.18	2696.74	327.3	252.34	3525.73	186.31	111.35	1551
15	74.95	268.09	193.14	2889.88	327.19	252.24	3777.97	185.96	111.01	1662.01
ID(cm)	L(cm)	Q/t (cm ³ /min)	k ₍₁₎ (cm/s)		Q/t (cm ³ /min)	k ₍₂₎ (cm/s)		Q/t (cm ³ /min)	k ₍₃₎ (cm/s)	
10.73	21.45	192.61	0.013324		251.82	0.013780		110.77	0.013537	
A(cm ²)	k _r (cm/s)	H(cm)			H(cm)			H(cm)		
90.425	0.013547	57.15			72.25			32.35

Figure A-14: Constant Head Test – Column DW, Avg. $10.82 \text{ cm}^3/\text{cm}^2/\text{day}$ HLR, 5-day HRT

APPENDIX B
COLUMN EXPERIMENT

Figure B-1: Spectrophotometer Wavelength Calibration Check

Figure B-2: COD Calibration Curve (Feb 2, 2004 to Feb 5, 2004)

Figure B-3: COD Calibration Curve (Feb 9, 2004 to Apr 21, 2004)

Figure B-4: COD Calibration Curve (Apr 24, 2004 to End)

Figure B-5: NH₃-N Calibration Curve

Figure B-6: NO₃⁻-N Calibration Curve

Figure B-7: H₂S Calibration Curve

Table B-1: COD (Absorbance) of 5-day HRT

Dated	Raw Leachate	Aerated Leachate	Distilled Water	Avg. 8.28 cm ³ /cm ² /day HLR			Avg. 10.82 cm ³ /cm ² /day HLR		
				Column 1	Column 2	Column 3	Column 1	Column 2	Column 3
2-Feb-04	0.315	0.224	0.093	0.171	0.057	0.089	0.120	0.078	0.104
	0.318	0.176	0.041	0.199	0.126	0.084	0.164	0.134	0.071
3-Feb-04	0.313	0.183	0.029	0.090	0.080	0.109	0.129	0.132	0.139
	0.312	0.165	0.027	0.091	0.097	0.107	0.125	0.131	0.141
4-Feb-04	0.301	0.161	0.053	0.165	0.139	0.141	0.151	0.151	0.150
	0.299	0.161	0.029	0.159	0.140	0.147	0.166	0.155	0.140
5-Feb-04	0.302	0.165	0.032	0.155	0.151	0.156	0.153	0.152	0.151
	0.310	0.174	0.028	0.160	0.154	0.151	0.155	0.148	0.164
9-Feb-04	0.272	0.230	0.011	0.193	0.204	0.220	0.246	0.235	0.215
	0.277	0.246	0.098	0.215	0.198	0.223	0.249	0.229	0.215
11-Feb-04	0.336	0.281	0.010	0.284	0.226	0.236	0.236	0.251	0.284
	0.333	0.285	0.007	0.239	0.228	0.249	0.287	0.245	0.266
13-Feb-04	0.332	0.287	0.011	0.243	0.267	0.266	0.306	0.288	0.257
	0.346	0.298	0.002	0.234	0.274	0.288	0.301	0.287	0.247
15-Feb-04	0.309	0.285	0.011	0.245	0.300	0.235	0.345	0.310	0.330
	0.319	0.285	0.005	0.275	0.320	0.210	0.360	0.370	0.315
16-Feb-04	0.308	0.298	0.008	0.326	0.316	0.318	0.340	0.322	0.345
	0.328	0.288	0.010	0.325	0.314	0.322	0.335	0.330	0.347
20-Feb-04	0.398	0.332	0.009	0.324	0.335	0.330	0.334	0.331	0.310
	0.401	0.333	0.047	0.335	0.330	0.348	0.332	0.326	0.313
22-Feb-04	0.310	0.308	0.012	0.328	0.316	0.334	0.303	0.324	0.292
	0.317	0.302	0.017	0.353	0.364	0.330	0.306	0.287	0.297
24-Feb-04	0.227	0.285	0.012	0.266	0.278	0.304	0.288	0.294	0.281
	0.223	0.299	0.012	0.274	0.287	0.291	0.300	0.274	0.278
26-Feb-04	0.283	0.274	0.004	0.201	0.262	0.246	0.239	0.269	0.308
	0.277	0.292	0.005	0.200	0.276	0.246	0.223	0.257	0.221
28-Feb-04	0.258	0.264	0.006	0.152	0.237	0.167	0.197	0.221	0.248
	0.271	0.267	0.001	0.159	0.223	0.158	0.198	0.229	0.249
1-Mar-04	0.359	0.234	0.008	0.150	0.171	0.143	0.185	0.146	0.208
	0.291	0.242	0.019	0.150	0.171	0.150	0.171	0.199	0.194
4-Mar-04	0.221	0.140	0.005	0.098	0.089	0.097	0.117	0.090	0.117
	0.228	0.130	0.011	0.101	0.126	0.091	0.114	0.108	0.111
7-Mar-04	0.250	0.096	0.000	0.071	0.073	0.074	0.078	0.074	0.083
	0.254	0.113	0.001	0.071	0.077	0.079	0.068	0.051	0.077
10-Mar-04	0.273	0.135	0.001	0.112	0.099	0.092	0.095	0.104	0.091
	0.227	0.113	0.031	0.101	0.102	0.102	0.115	0.099	0.100
13-Mar-04	0.261	0.105	0.000	0.080	0.096	0.109	0.123	0.117	0.119
	0.294	0.101	0.027	0.078	0.108	0.102	0.122	0.111	0.095
16-Mar-04	0.263	0.124	0.000	0.089	0.098	0.089	0.108	0.105	0.121
	0.266	0.139	0.027	0.095	0.088	0.089	0.111	0.106	0.094
19-Mar-04	0.200	0.137	0.017	0.101	0.108	0.092	0.112	0.111	0.096
	0.199	0.114	0.009	0.105	0.096	0.106	0.116	0.106	0.107
22-Mar-04	0.188	0.089	0.000	0.043	0.039	0.044	0.062	0.041	0.054
	0.191	0.134	0.000	0.048	0.043	0.040	0.046	0.045	0.058
25-Mar-04	0.213	0.092	0.008	0.061	0.037	0.070	0.095	0.029	0.055
	0.201	0.146	0.000	0.034	0.056	0.071	0.050	0.057	0.067
28-Mar-04	0.304	0.120	0.000	0.056	0.065	0.061	0.025	0.084	0.094
	0.294	0.111	0.000	0.074	0.078	0.077	0.061	0.045	0.087
31-Mar-04	0.284	0.079	0.030	0.060	0.089	0.080	0.062	0.069	0.039
	0.298	0.103	0.000	0.139	0.079	0.079	0.061	0.091	0.054
3-Apr-04	0.332	0.092	0.000	0.022	0.057	0.069	0.044	0.060	0.063
	0.295	0.076	0.000	0.054	0.082	0.044	0.059	0.029	0.056
4-Apr-04	0.293	0.053	0.000	0.025	0.050	0.058	0.047	0.037	0.039
	0.287	0.041	0.000	0.026	0.024	0.074	0.061	0.011	0.060
6-Apr-04	0.317	0.051	0.000	0.031	0.025	0.040	0.046	0.046	0.026
	0.310	0.077	0.000	0.044	0.056	0.038	0.050	0.033	0.046

Table B-1: Continued

Dated	Raw Leachate	Aerated Leachate	Distilled Water	Avg. 8.28 cm ³ /cm ² /day HLR			Avg. 10.82 cm ³ /cm ² /day HLR		
				Col. 1	Col. 2	Col. 3	Col. 1	Col. 2	Col. 3
9-Apr-04	0.291	0.056	0.000	0.041	0.027	0.026	0.032	0.029	0.048
	0.301	0.069	0.000	0.017	0.031	0.026	0.038	0.037	0.027
12-Apr-04	0.300	0.095	0.000	0.041	0.020	0.041	0.053	0.015	0.024
	0.299	0.074	0.000	0.028	0.031	0.023	0.097	0.021	0.032
16-Apr-04	0.296	0.086	0.000	0.031	0.028	0.025	0.053	0.029	0.031
	0.292	0.089	0.000	0.028	0.031	0.023	0.045	0.021	0.032
21-Apr-04	0.294	0.274	0.000	0.027	0.026	0.028	0.043	0.033	0.036
	0.293	0.310	0.000	0.027	0.040	0.020	0.030	0.023	0.021
24-Apr-04	0.370	0.371	0.024	0.068	0.068	0.113	0.096	0.099	0.087
	0.353	0.303	0.012	0.067	0.072	0.093	0.089	0.066	0.072
27-Apr-04	0.347	0.225	0.005	0.099	0.066	0.104	0.100	0.105	0.054
	0.354	0.209	0.001	0.103	0.064	0.101	0.066	0.087	0.080
30-Apr-04	0.358	0.325	0.006	0.060	0.084	0.071	0.080	0.054	0.060
	0.360	0.315	0.014	0.062	0.081	0.060	0.100	0.068	0.058
4-May-04	0.349	0.340	0.004	0.087	0.075	0.084	0.069	0.064	0.069
	0.341	0.351	0.029	0.057	0.077	0.088	0.065	0.074	0.067
8-May-04	0.290	0.316	0.003	0.052	0.037	0.076	0.064	0.054	0.065
	0.360	0.319	0.025	0.054	0.044	0.058	0.060	0.055	0.058
11-May-04	0.232	0.355	0.021	0.023	0.032	0.025	0.030	0.029	0.062
	0.217	0.367	0.021	0.064	0.025	0.030	0.033	0.023	0.030
14-May-04	0.361	0.333	0.026	0.050	0.023	0.051	0.036		
	0.340	0.331	0.016	0.027	0.025	0.028	0.035		
18-May-04	0.301	0.354	0.008		0.021	0.031	0.036		
	0.298	0.351	0.006		0.020	0.021	0.021		
25-May-04	0.312	0.325	0.005			0.025			
	0.301	0.342	0.004			0.021			

Table B-2: COD (mg O₂/L) of 5-day HRT

					Avg. 8.28 cm ³ /cm ² /day HLR				Avg. 10.82 cm ³ /cm ² /day HLR			
Date	Day	Raw Leachate	Aerated Leachate	Distilled Water	Col. 1	Col. 2	Col. 3	Col. Avg.	Col. 1	Col. 2	Col. 3	Col. Avg.
Feb 2	2	905.19	572.00	191.62	529.1	261.6	247.3	346.0	406.1	303.1	250.2	319.8
Feb 3	3	893.75	497.64	80.08	258.8	253.1	308.8	273.6	363.2	376.0	400.4	379.9
Feb 4	4	858.00	460.46	117.26	463.3	398.9	411.8	424.7	453.3	437.5	414.7	435.2
Feb 5	5	875.16	484.77	85.80	450.4	436.1	439.0	441.8	440.4	429.0	450.4	439.9
Feb 9	9	805.00	697.96	159.83	598.2	589.4	649.5	612.4	725.8	680.3	630.5	678.9
Feb 11	11	980.96	829.93	24.93	766.8	665.7	711.1	714.5	766.8	727.2	806.4	766.8
Feb 13	13	994.15	857.79	19.06	699.4	793.2	812.3	768.3	890.0	843.1	739.0	824.0
Feb 15	15	920.83	835.79	23.46	762.4	909.1	652.5	774.6	1033	997.0	945.7	992.1
Feb 16	16	932.57	859.25	26.39	954.5	923.7	938.4	938.9	989.7	956.0	1014	986.8
Feb 20	20	1171.5	975.09	82.11	966.2	975.0	994.1	978.5	976.5	963.3	913.5	951.1
Feb 22	22	919.37	894.44	42.52	998.5	997.0	973.6	989.7	892.9	895.9	863.6	884.1
Feb 24	24	659.84	856.32	35.19	791.8	828.4	872.4	830.9	862.1	832.8	819.6	838.2
Feb 26	26	821.13	829.93	13.20	587.9	788.8	721.4	699.4	677.4	771.2	775.6	741.4
Feb 28	28	775.67	778.61	10.26	456.0	674.5	476.5	535.6	579.1	659.8	728.7	655.9
Mar 1	30	953.10	697.96	39.59	439.8	501.4	429.6	457.0	522.0	505.8	589.4	539.1
Mar 4	33	658.37	395.90	23.46	291.7	315.2	275.6	294.2	338.7	290.3	334.3	321.1
Mar 7	36	739.02	306.46	1.47	208.2	219.9	224.3	217.5	214.0	183.2	234.6	210.6
Mar 10	39	733.15	363.64	46.92	312.3	294.7	284.4	297.1	307.9	297.6	280.0	295.2
Mar 13	42	813.80	302.06	39.59	231.6	299.1	309.3	280.0	359.2	334.3	313.7	335.7
Mar 16	45	775.67	385.64	39.59	269.8	272.7	261.0	267.8	321.1	309.3	315.2	315.2
Mar 19	48	585.05	368.04	38.12	302.0	299.1	290.3	297.1	334.3	318.1	297.6	316.7
Mar 22	51	555.73	326.99	0	133.4	120.2	123.1	125.6	158.3	126.1	164.2	149.5
Mar 25	54	607.05	348.98	11.73	139.3	136.3	206.7	160.8	212.6	126.1	178.8	172.5
Mar 28	57	876.85	338.72	0	190.6	209.6	202.3	200.8	126.1	189.1	265.4	193.5
Mar 31	60	853.39	266.87	43.99	291.7	335.7	309.3	312.3	180.3	234.6	136.3	183.7
Apr 3	63	919.37	246.34	0	111.4	203.8	165.6	160.3	151.	130.5	174.4	152.0
Apr 4	64	850.45	137.83	0	74.78	108.5	193.5	125.6	158.3	70.38	145.1	124.6
Apr 6	66	919.37	187.69	0	109.7	118.7	114.3	114.3	140.7	115.8	105.5	120.7
Apr 9	69	868.05	183.29	0	85.05	85.05	76.25	82.11	102.6	96.78	109.9	103.1
Apr 12	72	878.31	247.81	0	101.1	74.78	93.84	89.93	219.9	52.79	82.11	118.2
Apr 16	76	862.18	256.60	0	86.51	86.51	70.38	81.14	143.7	73.32	92.38	103.1
Apr 21	81	860.72	856.32	0	79.18	96.78	70.38	82.11	107.0	82.11	83.58	90.91
Apr 24	84	1243.5	1159.2	61.92	232.2	240.8	354.3	275.7	318.2	283.8	273.4	291.8
Apr 27	87	1205.7	746.48	10.32	347.4	223.6	352.6	307.8	285.5	330.2	230.4	282.0
Apr 30	90	1234.9	1100.8	34.40	209.8	283.8	225.3	239.6	309.6	209.8	202.9	240.8
May 4	94	1186.8	1188.5	56.76	247.6	261.4	295.8	268.3	230.4	237.3	233.9	233.9
May 8	98	1118.0	1092.2	48.16	182.3	139.3	230.4	184.0	213.2	187.4	211.5	204.1
May 11	101	772.28	1241.8	72.24	149.6	98.04	94.60	114.0	108.3	89.44	158.2	118.6
May 14	104	1205.7	1142.0	72.24	132.4 4	82.56	135.8	116.9	122.1	--	--	122.1
May 18	108	1030.2	1212.6	24.08	--	70.52	89.44	79.98	98.04	--	--	98.04
May 25	115	1054.3	1147.2	15.48	--	--	79.12	79.12	--	--	--	--
Minimum		556	138	0				79				91
Maximum		1244	1242	192				990				992
Average		899	651	39				356				383
Std. Dev		176	347	43				275				287
No. of Obs.		41	41	41				41				40

TableB-3: Cumulative COD Influent and Removal of Peat Columns in 5-day HRT

Wt. of Peat (Avg. 8.28 cm³/cm²/day) = ((975+810+975)/3)*(1-0.5104)=450.432 g of peat

Wt. of Peat (Avg. 10.82 cm³/cm²/day) = ((1020+775+970)/3)*(1-0.5104)=451.248 g of peat

Day	Day Interval	Aerated Leachate	Flow (mL/d) Avg. 8.28	Flow (mL/d) Avg. 10.82	Inf. COD (mg/g-d) Avg. 8.28	Cum. COD Inf. (mg/g) Avg. 8.28	Inf. COD (mg/g-d) Avg. 10.82	Cum. COD Inf. (mg/g) Avg. 10.82	COD (mg/L) Avg. 8.28	COD (mg/L) Avg. 10.82	COD Removal Avg. 8.28	Cum COD Removal Avg. 8.28	COD Removal Avg. 10.82	Cum COD Removal Avg. 10.82
2	2	572.00	670.33	882.67	0.85	1.70	1.12	2.24	346.06	319.84	0.34	0.67	0.49	0.99
3	1	497.64	645.67	866.67	0.71	2.42	0.96	3.19	273.61	379.90	0.32	0.99	0.23	1.21
4	1	460.46	645.00	859.33	0.66	3.08	0.88	4.07	424.71	435.20	0.05	1.04	0.05	1.26
5	1	484.77	652.33	845.67	0.70	3.78	0.91	4.98	441.87	439.96	0.06	1.11	0.08	1.34
9	4	697.96	639.67	862.17	0.99	7.74	1.33	10.31	612.42	678.90	0.12	1.59	0.04	1.49
11	2	829.93	628.00	843.33	1.16	10.06	1.55	13.42	714.58	766.87	0.16	1.91	0.12	1.73
13	2	857.79	630.50	854.17	1.20	12.46	1.62	16.66	768.34	824.06	0.13	2.16	0.06	1.85
15	2	835.79	633.00	865.00	1.17	14.81	1.60	19.87	774.70	992.20	0.09	2.34	-0.30	1.25
16	1	859.25	628.00	838.33	1.20	16.00	1.60	21.46	938.92	986.82	-0.11	2.23	-0.24	1.02
20	4	975.09	609.00	847.33	1.32	21.28	1.83	28.79	978.51	951.14	0.00	2.21	0.04	1.20
22	2	894.44	617.67	819.00	1.23	23.73	1.62	32.03	989.75	884.18	-0.13	1.95	0.02	1.23
24	2	856.32	623.67	832.00	1.19	26.10	1.58	35.19	830.90	838.23	0.04	2.02	0.03	1.30
26	2	829.93	605.00	783.67	1.11	28.33	1.44	38.07	699.43	741.46	0.18	2.37	0.15	1.61
28	2	778.61	613.33	806.00	1.06	30.45	1.39	40.86	535.69	655.92	0.33	3.03	0.22	2.05
30	2	697.96	616.67	792.67	0.96	32.36	1.23	43.31	457.00	539.11	0.33	3.69	0.28	2.60
33	3	395.90	621.67	785.33	0.55	34.00	0.69	45.37	294.24	321.12	0.14	4.11	0.13	2.99
36	3	306.46	607.33	794.67	0.41	35.24	0.54	46.99	217.50	210.66	0.12	4.47	0.17	3.50
39	3	363.64	595.67	784.00	0.48	36.69	0.63	48.89	297.17	295.22	0.09	4.73	0.12	3.86
42	3	302.06	564.00	737.67	0.38	37.82	0.49	50.37	280.06	335.78	0.03	4.82	-0.06	3.69
45	3	385.64	573.50	764.34	0.49	39.29	0.65	52.33	267.84	315.25	0.15	5.26	0.12	4.05
48	3	368.04	583.00	791.00	0.48	40.72	0.65	54.27	297.17	316.72	0.09	5.54	0.09	4.32
51	3	326.98	582.67	755.00	0.42	41.99	0.55	55.91	125.61	149.56	0.26	6.32	0.30	5.21
54	3	348.98	572.33	779.67	0.44	43.32	0.60	57.72	160.80	172.53	0.24	7.04	0.30	6.12
57	3	338.72	575.00	777.00	0.43	44.62	0.58	59.47	200.88	193.55	0.18	7.57	0.25	6.87
60	3	266.87	577.67	774.33	0.34	45.65	0.46	60.84	257.09	183.78	0.01	7.60	0.14	7.30
63	3	246.34	569.33	787.33	0.31	46.58	0.43	62.13	160.32	152.01	0.11	7.93	0.16	7.80
64	1	137.83	566.33	783.50	0.17	46.75	0.24	62.37	125.61	124.64	0.02	7.95	0.02	7.82
66	2	187.69	563.33	779.67	0.23	47.22	0.32	63.02	114.37	120.73	0.09	8.13	0.12	8.05
69	3	183.29	568.17	788.50	0.23	47.92	0.32	63.98	82.11	103.13	0.13	8.51	0.14	8.47
72	3	247.80	573.00	797.33	0.32	48.86	0.44	65.29	89.93	118.28	0.20	9.11	0.23	9.16
76	4	256.60	563.17	771.50	0.32	50.14	0.44	67.05	81.14	103.13	0.22	9.99	0.26	10.21
81	5	856.32	553.33	745.67	1.05	55.40	1.42	74.12	82.11	90.91	0.95	14.75	1.26	16.53
84	3	1159.28	538.33	731.00	1.39	59.56	1.88	79.75	275.77	291.83	1.06	17.92	1.41	20.75
87	3	746.48	541.67	757.67	0.90	62.25	1.25	83.51	307.88	282.08	0.53	19.50	0.78	23.09
90	3	1100.80	560.33	738.67	1.37	66.36	1.80	88.92	239.65	240.80	1.07	22.71	1.41	27.31
94	4	1188.52	572.00	714.33	1.51	72.40	1.88	96.45	268.32	233.92	1.17	27.39	1.51	33.35
98	4	1092.20	537.34	598.67	1.30	77.61	1.45	102.24	184.04	204.11	1.08	31.72	1.18	38.07
101	3	1241.84	502.67	483.00	1.39	81.77	1.33	106.23	114.09	118.68	1.26	35.49	1.20	41.67
104	3	1142.08	455.33	488.00	1.15	85.23	1.24	109.94	116.96	122.12	1.04	38.60	1.10	44.98
108	4	1212.60	430.00	300.00	1.16	89.86	0.81	113.16	79.98	98.04	1.08	42.93	0.74	47.95
115	7	1147.24	320.00	-	0.82	95.57			79.12		0.76	48.24		

Table B-4: COD (Absorbance) of 2-day HRT

Dated	Raw Leachate	Aerated Leachate	Distilled Water	Avg. 8.28 cm ³ /cm ² /day HLR			Avg. 10.82 cm ³ /cm ² /day HLR		
				Col. 1	Col. 2	Col. 3	Col. 1	Col. 2	Col. 3
6-Jul-04	0.320	0.252	0.043	0.057	0.071	0.031	0.037	0.033	0.046
	0.305	0.227	0.027	0.071	0.076	0.029	0.033	0.084	0.058
9-Jul-04	0.298	0.268	0.028	0.138	0.129	0.101	0.185	0.159	0.184
	0.314	0.266	0.026	0.205	0.130	0.101	0.178	0.162	0.174
12-Jul-04	0.320	0.299	0.012	0.162	0.125	0.152	0.201	0.169	0.189
	0.325	0.298	0.023	0.159	0.159	0.153	0.198	0.172	0.192
15-Jul-04	0.338	0.329	0.016	0.166	0.186	0.196	0.239	0.200	0.205
	0.323	0.294	0.003	0.165	0.175	0.208	0.207	0.184	0.185
20-Jul-04	0.330	0.357	0.038	0.303	0.261	0.278	0.268	0.228	0.306
	0.313	0.357	0.005	0.295	0.239	0.269	0.278	0.228	0.272
25-Jul-04	0.399	0.336	0.018	0.275	0.342	0.277	0.309	0.343	0.302
	0.412	0.336	0.026	0.275	0.325	0.268	0.310	0.351	0.308
30-Jul-04	0.365	0.339	0.015	0.169	0.269	0.201	0.252	0.229	0.252
	0.359	0.334	0.019	0.171	0.272	0.212	0.249	0.235	0.253
4-Aug-04	0.338	0.316	0.007	0.161	0.258	0.192	0.202	0.227	0.193
	0.346	0.354	0.026	0.162	0.246	0.189	0.188	0.218	0.194
9-Aug-04	0.335	0.277	0.000	0.065	0.102	0.055	0.079	0.072	0.089
	0.337	0.276	0.000	0.099	0.078	0.042	0.062	0.075	0.061
15-Aug-04	0.339	0.271	0.000	0.047	0.056	0.037	0.015	0.009	0.040
	0.340	0.312	0.000	0.041	0.037	0.024	0.042	0.008	0.020
20-Aug-04	0.272	0.152	0.002	0.039	0.042	0.031	0.032	0.015	0.045
	0.271	0.162	0.012	0.035	0.041	0.025	0.030	0.012	0.035
24-Aug-04	0.220	0.118	0.000	0.000	0.051	0.000	0.019	0.011	0.052
	0.233	0.106	0.000	0.007	0.018	0.005	0.017	0.010	0.041
30-Aug-04	0.252	0.152	0.003	0.057	0.045	0.015	0.025	0.042	0.035
	0.262	0.162	0.002	0.059	0.031	0.012	0.026	0.043	0.039
6-Sep-04	0.280	0.249	0.000	0.068	0.045	0.029	0.035	0.063	0.031
	0.279	0.276	0.000	0.028	0.049	0.022	0.029	0.057	0.030
14-Sep-04	0.280	0.271	0.000	0.103		0.103	0.062		0.069
	0.278	0.194	0.003	0.105		0.105	0.053		0.051
24-Sep-04	0.227	0.285	0.012	0.103		0.098	0.065		0.056
	0.223	0.185	0.012	0.098		0.089	0.065		0.065
27-Sep-04	0.283	0.274	0.004			0.078	0.063		
	0.277	0.175	0.005			0.102	0.059		

Table B-5: COD (mg O₂/L) of 2-day HRT

Date	Day	Raw Leachate	Aerated Leachate	Distilled Water	Avg. 8.28 cm ³ /cm ² /day HLR				Avg. 10.82 cm ³ /cm ² /day HLR			
					Col. 1	Col. 2	Col. 3	Col. Avg.	Col. 1	Col. 2	Col. 3	Col. Avg.
Jul 6	2	1075.00	823.88	120.40	220.16	252.84	103.20	192.06	120.40	201.24	178.88	166.84
Jul 9	5	1052.64	918.48	92.88	589.96	445.48	347.44	460.96	624.36	552.12	615.76	597.41
Jul 12	8	1109.40	1026.84	60.20	552.12	488.48	524.60	521.73	686.28	586.52	655.32	642.70
Jul 15	11	1136.92	1071.56	32.68	569.32	620.92	694.88	628.37	767.12	660.48	670.80	699.46
Jul 20	16	1105.96	1228.08	73.96	1028.5	860.00	940.84	943.13	939.12	784.32	994.16	905.86
Jul 25	21	1394.92	1155.84	75.68	946.00	1147.2	937.40	1010.2	1064.6	1193.6	1049.2	1102.5
Jul 30	26	1245.28	1157.56	58.48	584.80	930.52	710.36	741.89	861.72	798.08	868.60	842.80
Aug 4	31	1176.48	1152.40	56.76	555.56	866.88	655.32	692.58	670.80	765.40	665.64	700.61
Aug 9	36	1155.84	951.16	0.00	282.08	309.60	166.84	252.84	242.52	252.84	258.00	251.12
Aug 15	42	1167.88	1002.76	0.00	151.36	159.96	104.92	138.74	98.04	29.24	103.20	76.82
Aug 20	47	933.96	540.08	24.08	127.28	142.76	96.32	122.12	106.64	46.44	137.60	96.89
Aug 24	51	779.16	385.28	0.00	12.04	118.68	8.60	46.44	61.92	36.12	159.96	86.00
Aug 30	57	884.08	540.08	8.60	199.52	130.72	46.44	125.56	87.72	146.20	127.28	120.40
Sep 6	64	961.48	903.00	0.00	165.12	161.68	87.72	138.17	110.08	206.40	104.92	140.46
Sep 14	72	959.76	799.80	5.16	357.76		357.76	357.76	197.80		206.40	202.10
Sep 24	82	774.00	808.40	41.28	345.72		321.64	333.68	223.60		208.12	215.86
Sep 27	85	963.20	772.28	15.48			309.60	309.60	209.84			209.84
Minimum		774	385	0				46				77
Maximum		1395	1228	120				1010				1103
Average		1052	896	39				413				415
Std. Dev		163	241	37				299				340
No. of Obs.		17	17	17				17				17

TableB-6: Cumulative COD Influent and Removal of Peat Columns in 2-day HRT

Wt. of Peat (Avg. 8.28 cm³/cm²/day) = 850*(1-0.1421)=729.215 g of peat

Wt. of Peat (Avg. 10.82 cm³/cm²/day) = 850*(1-0.1421)=729.215 g of peat

Day	Day Interval	Aerated Leachate	Flow (mL/d) Avg. 8.28	Flow (mL/d) Avg. 10.82	Inf. COD (mg/g-d) Avg. 8.28	Cum. COD Inf. (mg/g) Avg. 8.28	Inf. COD (mg/g-d) Avg. 10.82	Cum. COD Inf. (mg/g) Avg. 10.82	COD (mg/L) Avg. 8.28	COD (mg/L) Avg. 10.82	COD Removal Avg. 8.28	Cum COD Removal Avg. 8.28	COD Removal Avg. 10.82	Cum COD Removal Avg. 10.82
2	2	823.88	587.33	818.33	0.66	1.33	0.92	1.85	192.07	166.84	0.51	1.02	0.74	1.47
5	3	918.48	604.67	835.33	0.76	3.61	1.05	5.01	460.96	597.41	0.38	2.16	0.37	2.58
8	3	1026.84	602.67	833.50	0.85	6.16	1.17	8.53	521.73	642.71	0.42	3.41	0.44	3.90
11	3	1071.56	600.67	831.67	0.88	8.81	1.22	12.19	628.37	699.47	0.37	4.50	0.42	5.17
16	5	1228.08	592.33	825.67	1.00	13.79	1.39	19.15	943.13	905.87	0.23	5.66	0.36	6.99
21	5	1155.84	580.67	823.67	0.92	18.40	1.31	25.67	1010.21	1102.52	0.12	6.24	0.06	7.29
26	5	1157.56	568.00	826.67	0.90	22.90	1.31	32.23	741.89	842.80	0.32	7.86	0.36	9.08
31	5	1152.40	561.00	826.00	0.89	27.34	1.31	38.76	692.59	700.61	0.35	9.63	0.51	11.64
36	5	951.16	567.33	816.67	0.74	31.04	1.07	44.09	252.84	251.12	0.54	12.34	0.78	15.56
42	6	1002.76	573.00	818.00	0.79	35.76	1.12	50.84	138.75	76.83	0.68	16.42	1.04	21.79
47	5	540.08	568.00	822.67	0.42	37.87	0.61	53.88	122.12	96.89	0.33	18.05	0.50	24.29
51	4	385.28	556.00	829.67	0.29	39.04	0.44	55.64	46.44	86.00	0.26	19.08	0.34	25.65
57	6	540.08	562.67	823.00	0.42	41.54	0.61	59.29	125.56	120.40	0.32	21.00	0.47	28.49
64	7	903.00	506.33	679.33	0.63	45.93	0.84	65.18	138.17	140.47	0.53	24.72	0.71	33.46
72	8	799.80	550.00	835.00	0.60	50.76	0.92	72.51	357.76	202.10	0.33	27.38	0.68	38.94
82	10	808.40	470.50	781.50	0.52	55.97	0.87	81.17	333.68	215.86	0.31	30.45	0.64	45.29
85	3	772.28	538.00	770.00	0.57	57.68	0.82	83.62	309.60	209.84	0.34	31.47	0.59	47.07

Table B-7: CBOD₅ (mg/L) of 5-day HRT

Date	Day	Raw Leachate	Aerated Leachate	Distilled Water	Avg. 8.28 cm ³ /cm ² /day HLR				Avg. 10.82 cm ³ /cm ² /day HLR			
					Col. 1	Col. 2	Col. 3	Col. Avg.	Col. 1	Col. 2	Col. 3	Col. Avg.
Feb13~18	13	150.00	25.27	28.70	47.30	16.85	42.05	35.40	77.90	19.70	28.55	42.05
Feb18~23	18	231.05	32.03	33.62	33.92	40.07	33.02	35.67	35.72	29.87	26.42	30.67
Feb21~26	21	353.00	20.20	6.05	16.70	15.05	11.90	14.55	25.55	18.50	28.55	24.20
Feb25~Mar1	25	346.03	13.42	7.01	16.16	27.56	35.81	26.51	51.71	15.26	70.61	45.86
Feb28~Mar4	28	295.35	76.88	24.64	53.89	43.54	65.14	54.19	74.44	63.19	49.69	62.44
Mar08~13	37	270.60	16.20	13.95	12.75	15.75	18.60	15.70	17.55	30.60	33.30	27.15
Mar11~16	40	223.20	37.50	17.10	30.30	23.70	24.45	26.15	25.20	29.25	25.65	26.70
Mar21~26	50	121.40	46.30	25.25	22.40	26.75	32.45	27.20	24.65	21.80	22.40	22.95
Apr10~15	70	427.40	40.00	20.15	15.05	20.15	24.05	19.75	15.20	12.50	14.45	14.05
Apr15~21	75	431.80	72.50	19.45	7.45	9.85	24.10	13.80	20.65	16.75	17.20	18.20
Apr24~29	84	506.00	220.90	8.75	17.60	8.45	7.10	11.05	10.55	8.30	12.80	10.55
Apr28~May3	88	287.00	141.10	4.40	4.70	14.45	7.85	9.00	10.25	9.35	4.70	8.10
May04~09	94	430.00	165.10	4.40	15.05	14.00	15.80	14.95	14.75	13.85	14.60	14.40
May08~13	98	450.25	238.90	4.10	30.95	10.55	15.80	19.10	14.30	14.90	33.95	21.05
May11~16	101	575.25	203.10	11.40	11.70	14.70	13.65	13.35	14.70	11.10	6.75	10.85
May20~25	110	348.00	221.70	3.30	15.75	9.15	13.35	12.75	12.30	-	-	12.30
Minimum												
		121	13	3				9				8
		575	239	34				54				62
		340	98	15				22				24
		126	85	10				12				15
		16	16	16				16				16

TableB-8: Cumulative BOD Influent and Removal of Peat Columns in 5-day HRT

Wt. of Peat (Avg. 8.28 cm³/cm²/day) = ((975+810+975)/3)*(1-0.5104)=450.432 g of peat

Wt. of Peat (Avg. 10.82 cm³/cm²/day) = ((1020+775+970)/3)*(1-0.5104)=451.248 g of peat

Day	Day Interval	Aerated Leachate	Flow (mL/d) Avg. 8.28	Flow (mL/d) Avg. 10.82	Inf. BOD (mg/g-d) Avg. 8.28	Cum BOD Inf. (mg/g) Avg. 8.28	Inf. BOD (mg/g-d) Avg. 10.82	Cum BOD Inf. (mg/g) Avg. 10.82	BOD (mg/L) Avg. 8.28	BOD (mg/L) Avg. 10.82	BOD Removal Avg.8.28	Cum BOD Removal Avg. 8.28	BOD Removal Avg.10.82	Cum BOD Removal Avg. 10.82
13	13	25.27	630.50	854.17	0.04	0.46	0.05	0.62	35.40	42.05	-0.01	-0.18	-0.03	-0.41
18	5	32.03	618.50	842.83	0.04	0.68	0.06	0.92	35.67	30.67	0.00	-0.21	0.00	-0.40
21	3	20.20	613.34	833.17	0.03	0.76	0.04	1.03	14.55	24.20	0.01	-0.19	-0.01	-0.42
25	4	13.42	614.34	807.84	0.02	0.84	0.02	1.13	26.51	45.86	-0.02	-0.26	-0.06	-0.65
28	3	76.88	613.33	806.00	0.10	1.15	0.14	1.54	54.19	62.44	0.03	-0.16	0.03	-0.58
37	9	16.20	607.33	794.67	0.02	1.35	0.03	1.80	15.70	27.15	0.00	-0.16	-0.02	-0.75
40	3	37.50	595.67	784.00	0.05	1.49	0.07	1.99	26.15	26.70	0.02	-0.11	0.02	-0.69
50	10	46.30	582.67	755.00	0.06	2.09	0.08	2.77	27.20	22.95	0.02	0.13	0.04	-0.30
70	20	40.00	569.77	791.44	0.05	3.11	0.07	4.17	19.75	14.05	0.03	0.65	0.05	0.61
75	5	72.50	566.44	780.11	0.09	3.56	0.13	4.80	13.80	18.20	0.07	1.01	0.09	1.08
84	9	220.90	538.33	731.00	0.26	5.94	0.36	8.02	11.05	10.55	0.25	3.27	0.34	4.14
88	4	141.10	541.67	757.67	0.17	6.62	0.24	8.97	9.00	8.10	0.16	3.91	0.22	5.04
94	6	165.10	572.00	714.33	0.21	7.87	0.26	10.53	14.95	14.40	0.19	5.05	0.24	6.47
98	4	238.90	537.34	598.67	0.28	9.01	0.32	11.80	19.10	21.05	0.26	6.10	0.29	7.62
101	3	203.10	502.67	483.00	0.23	9.69	0.22	12.45	13.35	10.85	0.21	6.74	0.21	8.24
110	9	221.70	430.00	-	0.21	11.60			12.75	12.30	0.20	8.53		

Table B-9: CBOD₅ (mg/L) of 2-day HRT

					Avg. 8.28 cm ³ /cm ² /day HLR				Avg. 10.82 cm ³ /cm ² /day HLR			
Date	Day	Raw Leachate	Aerated Leachate	Distilled Water	Col. 1	Col. 2	Col. 3	Col. Avg.	Col. 1	Col. 2	Col. 3	Col. Avg.
July 10~15	6	491.50	43.30	2.90	31.25	34.10	36.50	33.95	30.05	37.85	19.70	29.20
July 15~20	11	560.25	47.10	0.75	17.70	14.70	23.55	18.65	9.60	10.35	10.20	10.05
July 20~25	16	554.50	109.90	1.25	29.15	3.50	33.20	21.95	38.45	16.10	21.35	25.30
July 25~30	21	581.00	233.30	7.45	47.05	42.10	69.40	52.85	53.35	118.6	121.6	97.85
Aug 4~9	31	337.00	238.00	5.00	12.20	7.70	8.75	9.55	15.80	119.7	104.4	80.00
Aug 9~14	36	604.00	237.40	5.90	17.45	8.45	12.65	12.85	9.95	12.65	11.90	11.50
Aug 15~20	42	585.00	39.30	3.90	4.50	3.90	13.50	7.30	3.00	1.95	3.45	2.80
Aug 24~29	51	592.25	92.90	3.85	2.20	3.55	3.85	3.20	11.35	5.95	13.45	10.25
Sep06~11	64	500.20	132.20	4.12	8.30	12.31	9.16	9.92	10.65	9.62	10.45	10.24
Sep19~24	77	532.50	212.23	5.52	8.70		9.51	9.11	12.89		16.52	14.71
Minimum		337	39	1				3				3
Maximum		604	238	7				53				98
Average		534	139	4				18				29
Std. Dev		79	85	2				15				33
No. of Obs.		10	10	10				10				10

TableB-10: Cumulative BOD Influent & Removal of Peat Columns in 2-day HRT

Wt. of Peat (Avg. 8.28 cm³/cm²/day) = 850*(1-0.1421)=729.215 g of peat

Wt. of Peat (Avg. 10.82 cm³/cm²/day) = 850*(1-0.1421)=729.215 g of peat

Day	Day Interval	Aerated Leachate	Flow (mL/d) Avg. 8.28	Flow (mL/d) Avg. 10.82	Inf. BOD (mg/g-d) Avg. 8.28	Cum BOD Inf. (mg/g) Avg. 8.28	Inf. BOD (mg/g-d) Avg. 10.82	Cum BOD Inf. (mg/g) Avg. 10.82	BOD (mg/L) Avg. 8.28	BOD (mg/L) Avg. 10.82	BOD Removal Avg. 8.28	Cum BOD Removal Avg. 8.28	BOD Removal Avg. 10.82	Cum BOD Removal Avg. 10.82
6	6	43.30	604.67	835.33	0.04	0.22	0.05	0.30	33.95	29.20	0.01	0.05	0.02	0.10
11	5	47.10	600.67	831.67	0.04	0.41	0.05	0.57	18.65	10.05	0.02	0.16	0.04	0.31
16	5	109.90	592.33	825.67	0.09	0.86	0.12	1.19	21.95	25.30	0.07	0.52	0.10	0.79
21	5	233.30	580.67	823.67	0.19	1.78	0.26	2.51	52.85	97.85	0.14	1.24	0.15	1.55
31	10	238.00	561.00	826.00	0.18	3.62	0.27	5.20	9.55	80.00	0.18	3.00	0.18	3.34
36	5	237.40	567.33	816.67	0.18	4.54	0.27	6.53	12.85	11.50	0.17	3.87	0.25	4.61
42	6	39.30	573.00	818.00	0.03	4.72	0.04	6.80	7.30	2.80	0.03	4.02	0.04	4.85
51	9	92.90	556.00	829.67	0.07	5.36	0.11	7.75	3.20	10.25	0.07	4.64	0.09	5.70
64	13	132.20	506.33	679.33	0.09	6.56	0.12	9.35	9.92	10.24	0.08	5.74	0.11	7.18
77	13	212.23	550.00	825.00	0.16	8.64	0.24	12.47	9.11	14.71	0.15	7.73	0.22	10.08

Table B-11: Ammonia-N (mV) of 5-day HRT

				Avg. 8.28 cm ³ /cm ² /day HLR			Avg. 10.82 cm ³ /cm ² /day HLR		
Dated	Raw Leachate	Aerated Leachate	Distilled Water	Col. 1	Col. 2	Col. 3	Col. 1	Col. 2	Col. 3
2-Feb-04	-34.1	-31.2	151.6	82.9	113.4	97.1	42.6	94.6	23.7
3-Feb-04	-33.9	-30.9	150.2	27.4	81.6	34.5	5.1	27.7	-4.0
4-Feb-04	-33.6	-30.6	118.6	-2.5	35.5	-2.9	-11.2	-5.7	-16.3
5-Feb-04	-40.2	-37.0	84.4	-15.0	-2.9	-15.7	-23.1	-20.6	-25.6
9-Feb-04	-53.0	-49.3	129.1	-39.9	-35.9	-39.5	-41.7	-42.3	-43.5
11-Feb-04	-52.5	-48.7	136.9	-44.1	-40.7	-42.2	-45.9	-42.1	-41.9
15-Feb-04	-50.7	-5.9	127.8	-42.8	-45.1	-42.4	-43.9	-43.5	-43.2
16-Feb-04	-55.0	5.8	133.4	-41.7	-41.2	-41.9	-42.3	-41.6	-40.0
20-Feb-04	-46.8	33.8	127.2	-30.8	-9.1	-33.6	-22.2	17.5	14.2
22-Feb-04	-30.5	46.6	113.1	-11.4	20.8	-14.1	8.0	43.1	53.1
24-Feb-04	-37.7	31.2	116.5	1.2	43.6	2.5	31.6	72.1	68.6
26-Feb-04	-36.8	37.1	130.0	18.0	61.2	19.5	41.0	86.8	79.8
28-Feb-04	-41.6	108.9	146.8	39.5	77.2	38.5	55.6	94.7	86.3
1-Mar-04	-38.0	117.5	149.2	68.2	96.8	64.5	72.7	97.7	94.1
4-Mar-04	-39.4	99.2	141.4	90.4	115.0	91.6	89.3	112.7	94.8
7-Mar-04	-31.6	56.6	117.8	94.6	99.0	101.6	97.7	108.9	112.4
10-Mar-04	-41.3	144.3	146.1	110.6	110.2	102.8	102.5	107.5	96.6
13-Mar-04	-38.7	84.8	121.6	108.6	115.9	117.8	109.1	115.2	118.5
16-Mar-04	-38.4	56.4	90.7	99.3	113.8	115.2	114.4	115.9	117.1
19-Mar-04	-31.9	88.2	118.6	121.3	123.6	125.0	119.1	122.6	124.6
22-Mar-04	-52.6	61.5	106.2	108.2	110.8	114.3	115.3	115.1	108.7
25-Mar-04	-51.4	50.6	129.1	111.2	114.8	117.0	117.0	114.6	101.2
28-Mar-04	-33.4	45.1	102.7	105.2	112.6	114.8	115.1	120.1	101.9
31-Mar-04	-24.2	70.8	134.8	94.2	113.8	118.0	121.0	125.3	123.3
6-Apr-04	-28.8	75.8	143.1	122.1	128.3	130.0	131.7	134.9	137.9
9-Apr-04	-19.5	66.1	144.7	130.5	139.6	136.9	138.6	144.8	142.8
12-Apr-04	-26.8	76.4	145.6	120.5	130.6	128.3	130.4	134.8	136.2
24-Apr-04	-31.4	60.1	128.7	126.1	126.9	129.3	120.8	126.4	128.3
27-Apr-04	-30.9	102.5	133.8	133.6	131.3	130.7	124.4	125.1	126.5
30-Apr-04	-24.8	65.9	132.2	126.7	128.1	129.3	94.3	112.3	119.9
4-May-04	-27.8	75.6	125.1	109.0	111.7	113.9	103.7	92.4	99.0
8-May-04	-25.9	109.1	135.1	127.3	131.3	134.1	125.4	128.6	130.1
11-May-04	-21.4	88.7	124.7	118.2	117.7	116.5	117.4	123.6	121.1
14-May-04	-32.0	112.0	119.0	113.8	123.1	127.3	120.2		
18-May-04	-34.1	119.0	117.3		120.4	126.4	123.5		
25-May-04	-30.8	115.0	121.2			128.3			

Table B-12: Ammonia-N (mg/L) of 5-day HRT

					Avg. 8.28 cm ³ /cm ² /day HLR				Avg. 10.82 cm ³ /cm ² /day HLR			
Date	Day	Raw Leachate	Aerated Leachate	Distilled Water	Col. 1	Col. 2	Col. 3	Col. Avg.	Col. 1	Col. 2	Col. 3	Col. Avg.
Feb 2	2	436.50	388.13	0.24	3.82	1.11	2.15	2.36	19.54	2.38	42.01	21.31
Feb 3	3	432.98	383.45	0.25	36.16	4.03	27.13	22.44	89.23	35.73	128.99	84.65
Feb 4	4	427.75	378.82	0.90	121.39	26.05	123.37	90.27	172.66	138.19	212.28	174.38
Feb 5	5	558.83	490.90	3.60	201.39	123.37	207.18	177.31	279.58	252.66	309.37	280.54
Feb 9	9	938.47	807.87	0.59	552.08	469.51	543.21	521.60	593.83	608.44	638.74	613.67
Feb 11	11	919.66	788.47	0.43	654.45	570.26	605.98	610.23	703.94	603.53	598.66	635.38
Feb 15	15	855.00	139.31	0.62	620.89	681.50	610.91	637.77	649.17	638.74	631.03	639.65
Feb 16	16	1017.65	86.73	0.49	593.83	581.93	598.66	591.48	608.44	591.43	554.32	584.73
Feb 20	20	730.08	27.91	0.64	381.90	158.59	427.75	322.75	269.58	54.00	61.72	128.43
Feb 22	22	377.28	16.62	1.12	174.07	47.25	194.18	138.50	79.34	19.15	12.77	37.09
Feb 24	24	505.02	31.01	0.98	104.50	18.76	99.14	74.13	30.51	5.92	6.82	14.41
Feb 26	26	486.94	24.42	0.57	52.92	9.20	49.80	37.31	20.85	3.26	4.33	9.48
Feb 28	28	591.43	1.33	0.29	22.15	4.81	23.07	16.68	11.54	2.37	3.33	5.75
Mar 01	30	511.19	0.94	0.26	6.93	2.18	8.05	5.72	5.77	2.10	2.43	3.43
Mar 04	33	541.02	1.97	0.36	2.82	1.04	2.69	2.18	2.95	1.14	2.36	2.15
Mar 07	36	394.47	11.08	0.93	2.38	1.99	1.79	2.05	2.10	1.33	1.16	1.53
Mar 10	39	584.29	0.32	0.30	1.24	1.26	1.71	1.40	1.73	1.41	2.19	1.78
Mar 13	42	525.89	3.54	0.80	1.35	1.00	0.93	1.09	1.32	1.03	0.90	1.09
Mar 16	45	519.54	11.17	2.79	1.97	1.09	1.03	1.36	1.07	1.00	0.96	1.01
Mar 19	48	399.29	3.08	0.90	0.81	0.73	0.69	0.75	0.88	0.77	0.71	0.78
Mar 22	51	923.39	9.09	1.49	1.37	1.23	1.07	1.23	1.03	1.04	1.34	1.14
Mar 25	54	879.58	14.13	0.59	1.21	1.05	0.96	1.07	0.96	1.06	1.82	1.28
Mar 28	57	424.30	17.66	1.71	1.55	1.15	1.05	1.25	1.04	0.85	1.77	1.22
Mar 31	60	292.32	6.24	0.47	2.42	1.09	0.92	1.48	0.82	0.69	0.74	0.75
Apr 6	66	352.18	5.09	0.33	0.78	0.61	0.57	0.65	0.53	0.47	0.41	0.47
Apr 9	69	241.65	7.54	0.31	0.56	0.38	0.43	0.46	0.40	0.31	0.34	0.35
Apr 12	72	324.78	4.97	0.30	0.83	0.55	0.61	0.66	0.56	0.47	0.44	0.49
Apr 24	84	391.29	9.62	0.60	0.66	0.64	0.58	0.63	0.82	0.66	0.61	0.70
Apr 27	87	383.45	1.73	0.49	0.49	0.54	0.55	0.53	0.71	0.69	0.65	0.69
Apr 30	90	299.51	7.60	0.52	0.65	0.61	0.58	0.61	2.41	1.16	0.85	1.47
May 4	94	338.20	5.13	0.69	1.33	1.19	1.09	1.20	1.65	2.60	1.99	2.08
May 8	98	313.16	1.32	0.46	0.63	0.54	0.48	0.55	0.68	0.60	0.56	0.62
May 11	101	260.98	3.02	0.70	0.91	0.93	0.98	0.94	0.94	0.73	0.81	0.83
May 14	104	400.91	1.18	0.89	1.09	0.75	0.63	0.83	0.84			0.84
May 18	108	436.50	0.89	0.95		0.84	0.66	0.75	0.74			0.74
May 25	115	381.90	1.04	0.81			0.61	0.61				
Minimum		242	0	0				0				0
Maximum		1018	808	4				638				640
Average		511	103	1				91				93
Std. Dev		213	214	1				191				200
No. of Obs.		36	36	36				36				35

Table B-13: Ammonia-N (mV) of 2-day HRT

				Avg. 8.28 cm ³ /cm ² /day HLR			Avg. 10.82 cm ³ /cm ² /day HLR		
Dated	Raw Leachate	Aerated Leachate	Distilled Water	Col. 1	Col. 2	Col. 3	Col. 1	Col. 2	Col. 3
6-Jul-04	-33.9	-30.9	95.6	59.3	81.6	34.5	5.1	27.7	-4.0
9-Jul-04	-34.9	-30.4	73.7	52.2	49.3	52.2	0.8	10.2	-4.2
15-Jul-04	-33.9	-29.7	74.0	-20.7	-13.3	-22.3	-26.5	-26.4	-28.7
20-Jul-04	-31.2	-26.2	97.9	-24.8	-24.2	-27.2	-29.3	-30.4	-18.4
25-Jul-04	-34.2	47.7	105.5	-6.3	-25.2	-12.3	-7.3	-23.0	8.7
1-Aug-04	-27.9	14.1	98.7	20.3	-13.6	4.1	41.4	4.8	42.8
4-Aug-04	-28.9	24.1	99.2	30.5	-1.2	25.6	52.3	45.9	82.3
9-Aug-04	-25.4	31.9	111.7	56.9	24.5	86.1	103.7	76.8	106.7
15-Aug-04	-26.5	58.2	106.9	89.3	81.2	100.5	108.1	110.1	125.6
19-Aug-04	-28.3	50.1	95.3	89.1	75.9	103.2	112.0	115.3	128.3
24-Aug-04	-33.1	6.2	83.5	83.8	76.9	108.5	117.3	119.6	131.6
29-Aug-04	-31.6	0.2	102.5	74.9	85.2	104.3	116.4	105.3	115.9
6-Sep-04	-30.8	-8.1	109.2	68.2	96.8	94.5	112.5	97.7	94.1
14-Sep-04	-33.4	-21.9	108.4	80.8		79.3	74.5		75.1
24-Sep-04	-31.6	-29.9	107.8	42.4		0.6	58.8		32.7
27-Sep-04	-34.6	-30.1	146.1			-0.7	20.4		

Table B-14: Ammonia-N (mg/L) of 2-day HRT

					Avg. 8.28 cm ³ /cm ² /day HLR				Avg. 10.82 cm ³ /cm ² /day HLR			
Date	Day	Raw Leachate	Aerated Leachate	Distilled Water	Col. 1	Col. 2	Col. 3	Col. Avg.	Col. 1	Col. 2	Col. 3	Col. Avg.
6-Jul-04	2	432.98	383.45	2.28	9.94	4.03	27.13	13.70	89.23	35.73	128.99	84.65
9-Jul-04	5	450.88	375.76	5.55	13.25	14.90	13.25	13.80	106.20	72.58	130.04	102.94
15-Jul-04	11	432.98	365.26	5.48	253.69	187.99	270.67	237.45	320.86	319.56	350.76	330.39
20-Jul-04	16	388.13	316.98	2.08	299.51	292.32	330.08	307.31	359.39	375.76	231.12	322.09
25-Jul-04	21	438.28	15.89	1.53	141.58	304.40	180.53	208.84	147.44	278.45	77.12	167.67
1-Aug-04	28	339.58	61.97	2.01	48.21	190.29	92.92	110.47	20.51	90.32	19.38	43.40
4-Aug-04	31	353.61	41.33	1.97	31.96	115.16	38.90	62.01	13.19	17.10	3.91	11.40
9-Aug-04	36	306.88	30.14	1.19	10.95	40.67	3.36	18.33	1.65	4.89	1.46	2.66
15-Aug-04	42	320.86	10.39	1.45	2.95	4.09	1.87	2.97	1.38	1.27	0.68	1.11
19-Aug-04	46	345.12	14.42	2.31	2.97	5.07	1.68	3.24	1.18	1.03	0.61	0.94
24-Aug-04	51	419.18	85.34	3.73	3.68	4.87	1.35	3.30	0.95	0.86	0.53	0.78
29-Aug-04	56	394.47	108.82	1.73	5.28	3.48	1.61	3.46	0.98	1.54	1.00	1.18
6-Sep-04	64	381.90	152.29	1.32	6.93	2.18	2.39	3.83	1.15	2.10	2.43	1.89
14-Sep-04	72	424.30	266.32	1.36	4.16		4.42	4.29	5.37		5.24	5.30
24-Sep-04	82	394.47	368.23	1.39	19.70		107.07	63.38	10.14		29.18	19.66
27-Sep-04	85	445.43	371.22	0.30			112.85	112.85	48.02			48.02
Minimum		307	10	0				3				1
Maximum		451	383	6				307				330
Average		392	185	2				73				72
Std. Dev		47	156	1				97				110
No. of Obs.		16	16	16				16				16

Table B-15: Total NH₄⁺ Concentration of Aerated Leachate in 5-day HRT

Dated	Day	pH of Aerated Leachate	Temp. (deg C) of Aerated Leachate	Temp. (deg K)	p _{Ka}	f	Total Ammonia-N of Aerated Leachate (mg/L)	Total Ammonia (mg/L)	Total NH ₃ (mg/L)	Total NH ₄ ⁺ (mg/L)
2-Feb-04	2	8.91	22.00	295.00	9.34	0.2690086	388.13	471.30	126.78	344.52
3-Feb-04	3	8.89	22.00	295.00	9.34	0.2600497	383.45	465.62	121.08	344.53
4-Feb-04	4	8.88	22.00	295.00	9.34	0.2556436	378.82	460.00	117.59	342.40
5-Feb-04	5	8.87	22.00	295.00	9.34	0.2512867	490.9	596.09	149.79	446.30
9-Feb-04	9	8.89	21.50	294.50	9.36	0.2531491	807.87	980.99	248.34	732.65
11-Feb-04	11	8.86	22.00	295.00	9.34	0.2469794	788.47	957.43	236.46	720.96
15-Feb-04	15	7.25	22.00	295.00	9.34	0.0079868	139.31	169.16	1.35	167.81
16-Feb-04	16	7.22	22.00	295.00	9.34	0.0074577	86.73	105.32	0.79	104.53
20-Feb-04	20	8.06	22.00	295.00	9.34	0.0494135	27.91	33.89	1.67	32.22
22-Feb-04	22	8.14	22.50	295.50	9.33	0.0608482	16.62	20.18	1.23	18.95
24-Feb-04	24	8.32	22.00	295.00	9.34	0.0864175	31.01	37.66	3.25	34.40
26-Feb-04	26	8.25	22.50	295.50	9.33	0.0770365	24.42	29.65	2.28	27.37
28-Feb-04	28	8.07	22.50	295.50	9.33	0.0522636	1.33	1.62	0.08	1.53
1-Mar-04	30	8.32	22.50	295.50	9.33	0.0893067	0.94	1.14	0.10	1.04
4-Mar-04	33	8.23	22.00	295.00	9.34	0.0713976	1.97	2.40	0.17	2.23
7-Mar-04	36	7.94	22.00	295.00	9.34	0.0379365	11.08	13.46	0.51	12.95
10-Mar-04	39	8.38	22.50	295.50	9.33	0.1011989	0.32	0.39	0.04	0.35
13-Mar-04	42	8.10	22.00	295.00	9.34	0.0539237	3.54	4.30	0.23	4.06
19-Mar-04	48	8.36	22.50	295.50	9.33	0.0970864	3.08	3.74	0.36	3.38
22-Mar-04	51	7.93	22.00	295.00	9.34	0.037105	9.09	11.04	0.41	10.63
25-Mar-04	54	7.79	22.50	295.50	9.33	0.0281269	14.13	17.16	0.48	16.68
31-Mar-04	60	8.33	21.90	294.90	9.35	0.0876731	6.24	7.57	0.66	6.91
6-Apr-04	66	8.25	22.00	295.00	9.34	0.0745118	5.09	6.18	0.46	5.72
12-Apr-04	72	8.31	22.00	295.00	9.34	0.0846168	4.97	6.04	0.51	5.53
24-Apr-04	84	8.25	20.50	293.50	9.39	0.0673414	9.62	11.68	0.79	10.89
27-Apr-04	87	8.19	21.50	294.50	9.36	0.0633464	1.73	2.10	0.13	1.96
30-Apr-04	90	8.04	23.00	296.00	9.31	0.050646	7.60	9.23	0.47	8.77
4-May-04	94	8.10	20.50	293.50	9.39	0.0486305	5.13	6.23	0.30	5.93
11-May-04	101	7.82	21.50	294.50	9.36	0.0280408	3.02	3.67	0.10	3.56
14-May-04	104	8.38	23.00	296.00	9.31	0.1045144	1.18	1.43	0.15	1.28
18-May-04	108	8.14	23.00	296.00	9.31	0.0629343	0.89	1.08	0.07	1.01
25-May-04	115	8.14	23.00	296.00	9.31	0.0629343	1.04	1.26	0.08	1.18

Note: The last Column of This Table B-15 was used in calculation of NH₄⁺ CEC of each Column in Table B 16 to B 21 for 5-day HRT

Table B-16: Saturation of NH_4^+ Adsorption (Column 1, Avg. $8.28 \text{ cm}^3/\text{cm}^2/\text{day}$, 5-day HRT)

Dated	Day	Total NH_4^+ (mg/L) of Aerated Leachate	Flow rate of Column 1 (mL)	Total NH_4^+ (mg)	Cumulative Influent NH_4^+ (mg)	Total CEC for NH_4^+ (mg)	Remaining CEC for NH_4^+ (mg)
2-Feb-04	2	344.52	667.00	229.79	459.59	7399	6939.49
3-Feb-04	3	344.53	640.00	220.50	689.38	7399	6709.70
4-Feb-04	4	342.40	630.00	215.71	909.88	7399	6489.20
5-Feb-04	5	446.30	638.00	284.74	1125.59	7399	6273.49
9-Feb-04	9	732.65	611.00	447.65	2264.56	7399	5134.52
11-Feb-04	11	720.96	600.00	432.58	3159.85	7399	4239.23
15-Feb-04	15	167.81	614.00	103.04	4890.17	7399	2508.91
16-Feb-04	16	104.53	602.00	62.93	4993.20	7399	2405.88
20-Feb-04	20	32.22	597.00	19.23	5244.91	7399	2154.17
22-Feb-04	22	18.95	591.00	11.20	5283.37	7399	2115.71
24-Feb-04	24	34.40	606.00	20.85	5305.78	7399	2093.30
26-Feb-04	26	27.37	633.00	17.32	5347.47	7399	2051.61
28-Feb-04	28	1.53	596.00	0.91	5382.12	7399	2016.96
1-Mar-04	30	1.04	590.00	0.61	5383.94	7399	2015.14
4-Mar-04	33	2.23	590.00	1.31	5385.79	7399	2013.29
7-Mar-04	36	12.95	589.00	7.63	5389.73	7399	2009.35
10-Mar-04	39	0.35	575.00	0.20	5412.60	7399	1986.48
13-Mar-04	42	4.06	582.00	2.37	5413.20	7399	1985.88
19-Mar-04	48	3.38	569.00	1.92	5427.39	7399	1971.69
22-Mar-04	51	10.63	578.00	6.14	5433.16	7399	1965.92
25-Mar-04	54	16.68	574.00	9.57	5451.59	7399	1947.49
31-Mar-04	60	6.91	558.00	3.85	5509.03	7399	1890.05
6-Apr-04	66	5.72	544.00	3.11	5532.16	7399	1866.92
12-Apr-04	72	5.53	576.00	3.18	5550.84	7399	1848.24
24-Apr-04	84	10.89	522.00	5.69	5589.03	7399	1810.05
27-Apr-04	87	1.96	530.00	1.04	5606.09	7399	1792.99
30-Apr-04	90	8.77	531.00	4.66	5609.21	7399	1789.87
4-May-04	94	5.93	560.00	3.32	5627.83	7399	1771.25
11-May-04	101	3.56	425.00	1.52	5651.08	7399	1748.00
14-May-04	104	1.28	305.00	0.39	5655.63	7399	1743.45
18-May-04	108	1.01					
25-May-04	115	1.18					

Table B-17: Saturation of NH_4^+ Adsorption (Column 2, Avg. $8.28 \text{ cm}^3/\text{cm}^2/\text{day}$, 5-day HRT)

Dated	Day	Total NH_4^+ (mg/L) of Aerated Leachate)	Flow rate of Column 2 (mL)	Total NH_4^+ (mg)	Cumulative Influent NH_4^+ (mg)	Total CEC for NH_4^+ (mg)	Remaining CEC for NH_4^+ (mg)
2-Feb-04	2	344.52	678.00	233.58	467.16	6147	5679.76
3-Feb-04	3	344.53	660.00	227.39	700.75	6147	5446.18
4-Feb-04	4	342.40	655.00	224.27	928.14	6147	5218.79
5-Feb-04	5	446.30	683.00	304.82	1152.41	6147	4994.52
9-Feb-04	9	732.65	658.00	482.08	2371.71	6147	3775.22
11-Feb-04	11	720.96	654.00	471.51	3335.88	6147	2811.05
15-Feb-04	15	167.81	645.00	108.24	5221.92	6147	925.01
16-Feb-04	16	104.53	630.00	65.85	5330.15	6147	816.77
20-Feb-04	20	32.22	630.00	20.30	5593.57	6147	553.36
22-Feb-04	22	18.95	631.00	11.96	5634.16	6147	512.77
24-Feb-04	24	34.40	615.00	21.16	5658.08	6147	488.85
26-Feb-04	26	27.37	567.00	15.52	5700.39	6147	446.53
28-Feb-04	28	1.53	611.00	0.94	5731.43	6147	415.50
1-Mar-04	30	1.04	622.00	0.65	5733.30	6147	413.63
4-Mar-04	33	2.23	640.00	1.42	5735.24	6147	411.69
7-Mar-04	36	12.95	600.00	7.77	5739.52	6147	407.41
10-Mar-04	39	0.35	600.00	0.21	5762.82	6147	384.11
13-Mar-04	42	4.06	597.00	2.43	5763.45	6147	383.48
19-Mar-04	48	3.38	589.00	1.99	5778.00	6147	368.93
22-Mar-04	51	10.63	570.00	6.06	5783.97	6147	362.95
25-Mar-04	54	16.68	535.00	8.92	5802.14	6147	344.78
31-Mar-04	60	6.91	566.00	3.91	5855.68	6147	291.25
6-Apr-04	66	5.72	583.00	3.34	5879.14	6147	267.79
12-Apr-04	72	5.53	544.00	3.01	5899.16	6147	247.77
24-Apr-04	84	10.89	545.00	5.94	5935.23	6147	211.70
27-Apr-04	87	1.96	522.00	1.03	5953.04	6147	193.89
30-Apr-04	90	8.77	566.00	4.96	5956.12	6147	190.81
4-May-04	94	5.93	575.00	3.41	5975.96	6147	170.96
11-May-04	101	3.56	511.00	1.82	5999.84	6147	147.09
14-May-04	104	1.28	500.00	0.64	6005.30	6147	141.63
18-May-04	108	1.01	310	0.31	6007.22	6147	139.71
25-May-04	115	1.18				6147	

Table B-18: Saturation of NH_4^+ Adsorption (Column 3, Avg. $8.28 \text{ cm}^3/\text{cm}^2/\text{day}$, 5-day HRT)

Dated	Day	Total NH_4^+ (mg/L) of Aerated Leachate)	Flow rate of Column 3 (mL)	Total NH_4^+ (mg)	Cumulative Influent NH_4^+ (mg)	Total CEC for NH_4^+ (mg)	Remaining CEC for NH_4^+ (mg)
2-Feb-04	2	344.52	666.00	229.45	458.90	7399	6940.18
3-Feb-04	3	344.53	637.00	219.47	688.34	7399	6710.74
4-Feb-04	4	342.40	650.00	222.56	907.81	7399	6491.27
5-Feb-04	5	446.30	636.00	283.85	1130.37	7399	6268.71
9-Feb-04	9	732.65	650.00	476.22	2265.77	7399	5133.31
11-Feb-04	11	720.96	630.00	454.21	3218.21	7399	4180.87
15-Feb-04	15	167.81	640.00	107.40	5035.04	7399	2364.04
16-Feb-04	16	104.53	652.00	68.15	5142.44	7399	2256.64
20-Feb-04	20	32.22	600.00	19.33	5415.05	7399	1984.03
22-Feb-04	22	18.95	631.00	11.96	5453.71	7399	1945.37
24-Feb-04	24	34.40	650.00	22.36	5477.63	7399	1921.45
26-Feb-04	26	27.37	615.00	16.83	5522.35	7399	1876.73
28-Feb-04	28	1.53	633.00	0.97	5556.01	7399	1843.07
1-Mar-04	30	1.04	638.00	0.66	5557.95	7399	1841.13
4-Mar-04	33	2.23	635.00	1.41	5559.94	7399	1839.14
7-Mar-04	36	12.95	633.00	8.20	5564.18	7399	1834.90
10-Mar-04	39	0.35	612.00	0.21	5588.77	7399	1810.31
13-Mar-04	42	4.06	513.00	2.08	5589.41	7399	1809.67
19-Mar-04	48	3.38	591.00	2.00	5601.92	7399	1797.16
22-Mar-04	51	10.63	600.00	6.38	5607.91	7399	1791.17
25-Mar-04	54	16.68	608.00	10.14	5627.03	7399	1772.05
31-Mar-04	60	6.91	609.00	4.21	5687.88	7399	1711.20
6-Apr-04	66	5.72	563.00	3.22	5713.12	7399	1685.96
12-Apr-04	72	5.53	599.00	3.31	5732.45	7399	1666.63
24-Apr-04	84	10.89	548.00	5.97	5772.17	7399	1626.91
27-Apr-04	87	1.96	573.00	1.13	5790.07	7399	1609.01
30-Apr-04	90	8.77	584.00	5.12	5793.45	7399	1605.63
4-May-04	94	5.93	581.00	3.45	5813.93	7399	1585.15
11-May-04	101	3.56	572.00	2.04	5838.05	7399	1561.03
14-May-04	104	1.28	561.00	0.72	5844.17	7399	1554.91
18-May-04	108	1.01	550	0.55	5846.32	7399	1552.76
25-May-04	115	1.18	320.00	0.38	5847.98	7399	

Table B-19: Saturation of NH_4^+ Adsorption (Column 1, Avg. $10.82\text{cm}^3/\text{cm}^2/\text{day}$, 5-day HRT)

Dated	Day	Total NH_4^+ (mg/L) of Aerated Leachate	Flow rate of Column 1 (mL)	Total NH_4^+ (mg)	Cumulative Influent NH_4^+ (mg)	Total CEC for NH_4^+ (mg)	Remaining CEC for NH_4^+ (mg)
2-Feb-04	2	344.52	867.00	298.70	597.39	7741	7143.18
3-Feb-04	3	344.53	870.00	299.74	896.09	7741	6844.49
4-Feb-04	4	342.40	850.00	291.04	1195.83	7741	6544.74
5-Feb-04	5	446.30	830.00	370.43	1486.87	7741	6253.70
9-Feb-04	9	732.65	880.00	644.73	2968.60	7741	4771.98
11-Feb-04	11	720.96	845.00	609.21	4258.06	7741	3482.51
15-Feb-04	15	167.81	840.00	140.96	6694.92	7741	1045.66
16-Feb-04	16	104.53	811.00	84.77	6835.88	7741	904.70
20-Feb-04	20	32.22	816.00	26.29	7174.97	7741	565.60
22-Feb-04	22	18.95	784.00	14.86	7227.55	7741	513.03
24-Feb-04	24	34.40	800.00	27.52	7257.27	7741	483.31
26-Feb-04	26	27.37	762.00	20.85	7312.31	7741	428.27
28-Feb-04	28	1.53	793.00	1.21	7354.02	7741	386.56
1-Mar-04	30	1.04	794.00	0.83	7356.45	7741	384.13
4-Mar-04	33	2.23	817.00	1.82	7358.92	7741	381.65
7-Mar-04	36	12.95	779.00	10.09	7364.38	7741	376.20
10-Mar-04	39	0.35	762.00	0.26	7394.64	7741	345.94
13-Mar-04	42	4.06	748.00	3.04	7395.43	7741	345.14
19-Mar-04	48	3.38	786.00	2.66	7413.67	7741	326.91
22-Mar-04	51	10.63	745.00	7.92	7421.64	7741	318.94
25-Mar-04	54	16.68	770.00	12.84	7445.39	7741	295.19
31-Mar-04	60	6.91	757.00	5.23	7522.44	7741	218.14
6-Apr-04	66	5.72	756.00	4.33	7553.82	7741	186.76
12-Apr-04	72	5.53	779.00	4.30	7579.78	7741	160.80
24-Apr-04	84	10.89	676.00	7.36	7631.43	7741	109.15
27-Apr-04	87	1.96	722.00	1.42	7653.52	7741	87.06
30-Apr-04	90	8.77	697.00	6.11	7657.77	7741	82.80
4-May-04	94	5.93	670.00	3.97	7682.22	7741	58.36
11-May-04	101	3.56	652.00	2.32	7710.03	7741	30.54
14-May-04	104	1.28	488.00	0.62	7717.01	7741	23.57
18-May-04	108	1.01	300	0.30	7718.88	7741	21.70
25-May-04	115	1.18				7741	

Table B-20: Saturation of NH_4^+ Adsorption (Column2, Avg. $10.82 \text{ cm}^3/\text{cm}^2/\text{day}$, 5-day HRT)

Dated	Day	Total NH_4^+ (mg/L) of Aerated Leachate	Flow rate of Column 2 (mL)	Total NH_4^+ (mg)	Cumulative Influent NH_4^+ (mg)	Total CEC for NH_4^+ (mg)	Remaining CEC for NH_4^+ (mg)
2-Feb-04	2	344.52	895.00	308.34	616.69	5881	5264.63
3-Feb-04	3	344.53	850.00	292.85	925.03	5881	4956.29
4-Feb-04	4	342.40	825.00	282.48	1217.88	5881	4663.44
5-Feb-04	5	446.30	817.00	364.63	1500.36	5881	4380.96
9-Feb-04	9	732.65	848.00	621.29	2958.88	5881	2922.44
11-Feb-04	11	720.96	809.00	583.26	4201.45	5881	1679.87
15-Feb-04	15	167.81	836.00	140.29	6534.49	5881	0
16-Feb-04	16	104.53	814.00	85.09	6674.78	5881	0
20-Feb-04	20	32.22	816.00	26.29	7015.13	5881	0
22-Feb-04	22	18.95	800.00	15.16	7067.70	5881	0
24-Feb-04	24	34.40	805.00	27.69	7098.03	5881	0
26-Feb-04	26	27.37	763.00	20.88	7153.41	5881	0
28-Feb-04	28	1.53	777.00	1.19	7195.18	5881	0
1-Mar-04	30	1.04	797.00	0.83	7197.56	5881	0
4-Mar-04	33	2.23	807.00	1.80	7200.05	5881	0
7-Mar-04	36	12.95	800.00	10.36	7205.43	5881	0
10-Mar-04	39	0.35	795.00	0.28	7236.51	5881	0
13-Mar-04	42	4.06	745.00	3.03	7237.34	5881	0
19-Mar-04	48	3.38	788.00	2.66	7255.50	5881	0
22-Mar-04	51	10.63	745.00	7.92	7263.49	5881	0
25-Mar-04	54	16.68	795.00	13.26	7287.24	5881	0
31-Mar-04	60	6.91	771.00	5.33	7366.79	5881	0
6-Apr-04	66	5.72	758.00	4.34	7398.75	5881	0
12-Apr-04	72	5.53	784.00	4.33	7424.78	5881	0
24-Apr-04	84	10.89	762.00	8.30	7476.76	5881	0
27-Apr-04	87	1.96	790.00	1.55	7501.66	5881	0
30-Apr-04	90	8.77	755.00	6.62	7506.32	5881	0
4-May-04	94	5.93	761.00	4.51	7532.79	5881	0
11-May-04	101	3.56	242.00	0.86	7564.39	5881	0
14-May-04	104	1.28				5881	
18-May-04	108	1.01				5881	
25-May-04	115	1.18				5881	

Table B-21: Saturation of NH_4^+ Adsorption (Column 3, Avg. $10.82\text{cm}^3/\text{cm}^2/\text{day}$, 5-day HRT)

Dated	Day	Total NH_4^+ (mg/L) of Aerated Leachate	Flow rate of Column 3 (mL)	Total NH_4^+ (mg)	Cumulative Influent NH_4^+ (mg)	Total CEC for NH_4^+ (mg)	Remaining CEC for NH_4^+ (mg)
2-Feb-04	2	344.51677	886	305.241857	610.483714	7361.136	6750.652286
3-Feb-04	3	344.53405	880	303.1899676	915.725571	7361.136	6445.410429
4-Feb-04	4	342.40077	903	309.1878989	1218.915539	7361.136	6142.220461
5-Feb-04	5	446.30266	890	397.2093717	1528.103438	7361.136	5833.032562
9-Feb-04	9	732.64949	858.5	628.9795844	3116.940924	7361.136	4244.195076
11-Feb-04	11	720.96289	876	631.5634912	4374.900093	7361.136	2986.235907
15-Feb-04	15	167.81108	919	154.2183854	6901.154058	7361.136	459.981942
16-Feb-04	16	104.5296	890	93.03134034	7055.372443	7361.136	305.7635566
20-Feb-04	20	32.216056	910	29.31661074	7427.497805	7361.136	0
22-Feb-04	22	18.953425	873	16.54633975	7486.131026	7361.136	0
24-Feb-04	24	34.400949	891	30.65124576	7519.223706	7361.136	0
26-Feb-04	26	27.368505	826	22.60638485	7580.526197	7361.136	0
28-Feb-04	28	1.5305942	848	1.29794391	7625.738967	7361.136	0
1-Mar-04	30	1.040401	787	0.818795615	7628.334855	7361.136	0
4-Mar-04	33	2.2260545	732	1.629471915	7630.791242	7361.136	0
7-Mar-04	36	12.94786	805	10.42302733	7635.679657	7361.136	0
10-Mar-04	39	0.3468239	795	0.275725007	7666.948739	7361.136	0
13-Mar-04	42	4.0636162	720	2.925803694	7667.775914	7361.136	0
19-Mar-04	48	3.3793284	799	2.700083429	7685.330737	7361.136	0
22-Mar-04	51	10.626432	775	8.235484458	7693.430987	7361.136	0
25-Mar-04	54	16.677748	774	12.90857675	7718.13744	7361.136	0
31-Mar-04	60	6.9084719	795	5.492235153	7795.588901	7361.136	0
6-Apr-04	66	5.7234486	825	4.721845121	7828.542312	7361.136	0
12-Apr-04	72	5.525053	829	4.580268898	7856.873382	7361.136	0
24-Apr-04	84	10.893206	755	8.224370875	7911.836609	7361.136	0
27-Apr-04	87	1.9644527	761	1.494948497	7936.509722	7361.136	0
30-Apr-04	90	8.7668873	764	6.697901897	7940.994567	7361.136	0
4-May-04	94	5.9313548	712	4.22312459	7967.786175	7361.136	0
11-May-04	101	3.5648213	555	1.978475803	7997.348047	7361.136	0
14-May-04	104	1.2782811				7361.136	
18-May-04	108	1.007431				7361.136	
25-May-04	115	1.184598				7361.136	

Table B-22: Total NH_4^+ Concentration of Aerated Leachate in 2-day HRT

Dated	Day	pH of Aerated Leachate	Temp. (deg C) of Aerated Leachate	Temp. (deg K)	pKa	f	Total Ammonia-N of Aerated Leachate (mg/L)	Total Ammonia (mg/L)	Total NH_3 (mg/L)	Total NH_4^+ (mg/L)
6-Jul-04	2	8.77	19.50	292.50	9.42	0.1818088	383.45	465.61	84.65	380.96
9-Jul-04	5	8.93	20.00	293.00	9.41	0.2499172	375.76	456.28	114.03	342.25
15-Jul-04	11	8.85	19.50	292.50	9.42	0.2108294	365.26	443.53	93.51	350.02
20-Jul-04	16	8.89	19.50	292.50	9.42	0.2265614	316.98	384.91	87.21	297.70
25-Jul-04	21	8.12	19.00	292.00	9.44	0.045755	15.89	19.30	0.88	18.42
1-Aug-04	28	8.16	18.00	291.00	9.47	0.0465531	61.97	75.25	3.50	71.75
4-Aug-04	31	8.18	19.00	292.00	9.44	0.0521801	41.33	50.19	2.62	47.57
9-Aug-04	36	8.24	18.50	291.50	9.46	0.0574197	30.14	36.60	2.10	34.50
15-Aug-04	42	8.11	21.00	294.00	9.38	0.0514559	10.39	12.61	0.65	11.96
19-Aug-04	46	8.14	22.00	295.00	9.34	0.0588202	14.42	17.51	1.03	16.48
24-Aug-04	51	8.27	20.50	293.50	9.39	0.070292	85.34	103.63	7.28	96.34
29-Aug-04	56	8.26	22.50	295.50	9.33	0.0786897	108.82	132.13	10.40	121.74
6-Sep-04	64	8.25	21.50	294.50	9.36	0.0720551	152.29	184.93	13.32	171.60
14-Sep-04	72	8.36	22.00	295.00	9.34	0.0939714	266.32	323.39	30.39	293.00
24-Sep-04	82	8.32	19.50	292.50	9.42	0.0730806	368.23	447.13	32.68	414.46
27-Sep-04	85	8.23	20.50	293.50	9.39	0.064506	371.22	450.77	29.08	421.69
25-Oct-04	93	8.31	21.50	294.50	9.36	0.0818565	371.22	450.77	36.90	413.87

Note: The last Column of This Table B-22 was used in calculation of NH_4^+ CEC of each Column in Table B 23 to B28 for 2-day HRT

Table B-23: Saturation of NH_4^+ Adsorption (Column 1, Avg. $8.28 \text{ cm}^3/\text{cm}^2/\text{day}$, 2-day HRT)

Dated	Day	Total NH_4^+ (mg/L) of Aerated Leachate	Flow rate of Column 1 (mL)	Total NH_4^+ (mg)	Cumulative Influent NH_4^+ (mg)	Total CEC for NH_4^+ (mg)	Remaining CEC for NH_4^+ (mg)
6-Jul-04	2	380.96	611.00	232.77	465.53	11303	10837.30
9-Jul-04	5	342.25	625.00	213.90	1163.83	11303	10139.00
15-Jul-04	11	350.02	621.00	217.36	2447.26	11303	8855.57
20-Jul-04	16	297.70	610.00	181.60	3534.07	11303	7768.77
25-Jul-04	21	18.42	584.00	10.75	4442.06	11303	6860.77
1-Aug-04	28	71.75	568.00	40.75	4517.35	11303	6785.49
4-Aug-04	31	47.57	558.00	26.55	4639.61	11303	6663.23
9-Aug-04	36	34.50	572.00	19.73	4772.34	11303	6530.50
15-Aug-04	42	11.96	576.00	6.89	4890.72	11303	6412.11
19-Aug-04	46	16.48	565.00	9.31	4918.29	11303	6384.54
24-Aug-04	51	96.34	558.00	53.76	4964.85	11303	6337.98
29-Aug-04	56	121.74	542.00	65.98	5233.65	11303	6069.18
6-Sep-04	64	171.60	535.00	91.81	5761.49	11303	5541.34
14-Sep-04	72	293.00	515.00	150.89	6495.94	11303	4806.89
24-Sep-04	82	414.46	361.00	149.62	8004.89	11303	3297.94
27-Sep-04	85	421.69					
25-Oct-04	93	413.87					

Table B-24: Saturation of NH_4^+ Adsorption (Column 2, Avg. $8.28 \text{ cm}^3/\text{cm}^2/\text{day}$, 2-day HRT)

Dated	Day	Total NH_4^+ (mg/L) of Aerated Leachate	Flow rate of Column 2 (mL)	Total NH_4^+ (mg)	Cumulative Influent NH_4^+ (mg)	Total CEC for NH_4^+ (mg)	Remaining CEC for NH_4^+ (mg)
6-Jul-04	2	380.96	528.00	201.15	402.29	11303	10900.54
9-Jul-04	5	342.25	582.00	199.19	1005.74	11303	10297.10
15-Jul-04	11	350.02	580.00	203.01	2200.86	11303	9101.97
20-Jul-04	16	297.70	578.00	172.07	3215.91	11303	8086.92
25-Jul-04	21	18.42	571.00	10.52	4076.28	11303	7226.56
1-Aug-04	28	71.75	555.00	39.82	4149.88	11303	7152.95
4-Aug-04	31	47.57	545.00	25.93	4269.35	11303	7033.48
9-Aug-04	36	34.50	536.00	18.49	4398.98	11303	6903.85
15-Aug-04	42	11.96	556.00	6.65	4509.92	11303	6792.91
19-Aug-04	46	16.48	550.00	9.06	4536.53	11303	6766.30
24-Aug-04	51	96.34	542.00	52.22	4581.85	11303	6720.98
29-Aug-04	56	121.74	551.00	67.08	4842.95	11303	6459.89
6-Sep-04	64	171.60	393.00	67.44	5379.55	11303	5923.28
14-Sep-04	72	293.00					
24-Sep-04	82	414.46					
27-Sep-04	85	421.69					
25-Oct-04	93	413.87					

Table B-25: Saturation of NH_4^+ Adsorption (Column 3, Avg. $8.28 \text{ cm}^3/\text{cm}^2/\text{day}$, 2-day HRT)

Dated	Day	Total NH_4^+ (mg/L) of Aerated Leachate	Flow rate of Column 3 (mL)	Total NH_4^+ (mg)	Cumulative Influent NH_4^+ (mg)	Total CEC for NH_4^+ (mg)	Remaining CEC for NH_4^+ (mg)
6-Jul-04	2	380.96	623.00	237.34	474.68	11303	10828.16
9-Jul-04	5	342.25	607.00	207.74	1186.69	11303	10116.14
15-Jul-04	11	350.02	601.00	210.36	2433.16	11303	8869.68
20-Jul-04	16	297.70	589.00	175.35	3484.96	11303	7817.87
25-Jul-04	21	18.42	587.00	10.81	4361.69	11303	6941.14
1-Aug-04	28	71.75	581.00	41.69	4437.37	11303	6865.47
4-Aug-04	31	47.57	580.00	27.59	4562.43	11303	6740.41
9-Aug-04	36	34.50	594.00	20.49	4700.39	11303	6602.45
15-Aug-04	42	11.96	587.00	7.02	4823.33	11303	6479.50
19-Aug-04	46	16.48	589.00	9.71	4851.42	11303	6451.41
24-Aug-04	51	96.34	568.00	54.72	4899.96	11303	6402.87
29-Aug-04	56	121.74	595.00	72.43	5173.58	11303	6129.26
6-Sep-04	64	171.60	591.00	101.42	5753.03	11303	5549.80
14-Sep-04	72	293.00	585.00	171.40	6564.36	11303	4738.47
24-Sep-04	82	414.46	580.00	240.38	7935.60	11303	3367.23
27-Sep-04	85	421.69	538.00	226.87	9858.68	11303	1444.15
25-Oct-04	93	413.87	372.00	153.96	11673.64	11303	0

Table B-26: Saturation of NH_4^+ Adsorption (Column 1, Avg. $10.82\text{cm}^3/\text{cm}^2/\text{day}$, 2-day HRT)

Dated	Day	Total NH_4^+ (mg/L) of Aerated Leachate	Flow rate of Column 1 (mL)	Total NH_4^+ (mg)	Cumulative Influent NH_4^+ (mg)	Total CEC for NH_4^+ (mg)	Remaining CEC for NH_4^+ (mg)
6-Jul-04	2	380.96	815.00	310.48	620.97	11303	10681.87
9-Jul-04	5	342.25	853.00	291.94	1552.41	11303	9750.42
15-Jul-04	11	350.02	840.00	294.01	3304.04	11303	7998.80
20-Jul-04	16	297.70	824.00	245.31	4774.11	11303	6528.72
25-Jul-04	21	18.42	814.00	14.99	6000.65	11303	5302.19
1-Aug-04	28	71.75	815.00	58.48	6105.58	11303	5197.25
4-Aug-04	31	47.57	821.00	39.06	6281.01	11303	5021.82
9-Aug-04	36	34.50	815.00	28.11	6476.30	11303	4826.54
15-Aug-04	42	11.96	812.00	9.72	6644.98	11303	4657.86
19-Aug-04	46	16.48	819.00	13.50	6683.84	11303	4618.99
24-Aug-04	51	96.34	821.00	79.10	6751.33	11303	4551.50
29-Aug-04	56	121.74	829.00	100.92	7146.82	11303	4156.01
6-Sep-04	64	171.60	824.00	141.40	7954.17	11303	3348.66
14-Sep-04	72	293.00	820.00	240.26	9085.36	11303	2217.47
24-Sep-04	82	414.46	803.00	332.81	11007.44	11303	295.39
27-Sep-04	85	421.69	770.00	324.70	13669.90	11303	0
25-Oct-04	93	413.87	558.00	230.94	16267.53	11303	0

Table B-27: Saturation of NH_4^+ Adsorption (Column 2, Avg. $10.82\text{cm}^3/\text{cm}^2/\text{day}$, 2-day HRT)

Dated	Day	Total NH_4^+ (mg/L) of Aerated Leachate	Flow rate of Column 2 (mL)	Total NH_4^+ (mg)	Cumulative Influent NH_4^+ (mg)	Total CEC for NH_4^+ (mg)	Remaining CEC for NH_4^+ (mg)
6-Jul-04	2	380.96	780.00	297.15	594.30	11303	10708.53
9-Jul-04	5	342.25	834.00	285.43	1485.75	11303	9817.09
15-Jul-04	11	350.02	830.00	290.51	3198.35	11303	8104.48
20-Jul-04	16	297.70	818.00	243.52	4650.92	11303	6651.91
25-Jul-04	21	18.42	812.00	14.95	5868.53	11303	5434.30
1-Aug-04	28	71.75	819.00	58.76	5973.21	11303	5329.63
4-Aug-04	31	47.57	809.00	38.49	6149.50	11303	5153.34
9-Aug-04	36	34.50	791.00	27.29	6341.93	11303	4960.90
15-Aug-04	42	11.96	800.00	9.57	6505.64	11303	4797.19
19-Aug-04	46	16.48	780.00	12.86	6543.93	11303	4758.90
24-Aug-04	51	96.34	812.00	78.23	6608.21	11303	4694.62
29-Aug-04	56	121.74	768.00	93.49	6999.36	11303	4303.47
6-Sep-04	64	171.60	340.00	58.34	7747.30	11303	3555.53
14-Sep-04	72	293.00					
24-Sep-04	82	414.46					
27-Sep-04	85	421.69					
25-Oct-04	93	413.87					

Table B-28: Saturation of NH_4^+ Adsorption (Column 3, Avg. $10.82\text{cm}^3/\text{cm}^2/\text{day}$, 2-day HRT)

Dated	Day	Total NH_4^+ (mg/L) of Aerated Leachate	Flow rate of Column 3 (mL)	Total NH_4^+ (mg)	Cumulative Influent NH_4^+ (mg)	Total CEC for NH_4^+ (mg)	Remaining CEC for NH_4^+ (mg)
6-Jul-04	2	380.96	860.00	327.63	655.25	11303	10647.58
9-Jul-04	5	342.25	819.00	280.30	1638.13	11303	9664.70
15-Jul-04	11	350.02	825.00	288.76	3319.93	11303	7982.90
20-Jul-04	16	297.70	835.00	248.58	4763.76	11303	6539.08
25-Jul-04	21	18.42	845.00	15.56	6006.67	11303	5296.17
1-Aug-04	28	71.75	846.00	60.70	6115.60	11303	5187.24
4-Aug-04	31	47.57	848.00	40.34	6297.70	11303	5005.14
9-Aug-04	36	34.50	844.00	29.11	6499.41	11303	4803.43
15-Aug-04	42	11.96	842.00	10.07	6674.09	11303	4628.74
19-Aug-04	46	16.48	869.00	14.32	6714.39	11303	4588.44
24-Aug-04	51	96.34	856.00	82.47	6786.00	11303	4516.83
29-Aug-04	56	121.74	872.00	106.15	7198.35	11303	4104.48
6-Sep-04	64	171.60	874.00	149.98	8047.57	11303	3255.26
14-Sep-04	72	293.00	850.00	249.05	9247.41	11303	2055.42
24-Sep-04	82	414.46	760.00	314.99	11239.81	11303	63.03
27-Sep-04	85	421.69					
25-Oct-04	93	413.87					

Table B-29: Nitrate-N (mV) of 5-day HRT

				Avg. 8.28 cm ³ /cm ² /day HLR			Avg. 10.82 cm ³ /cm ² /day HLR		
Dated	Raw Leachate	Aerated Leachate	Distilled Water	Col. 1	Col. 2	Col. 3	Col. 1	Col. 2	Col. 3
2-Feb-04	68.9	60.5	55.2	72.1	70.1	82.1	80.3	79.3	95.1
5-Feb-04	71.2	56.2	59.2	65.4	38.5	75.2	75.3	70.5	80.8
8-Feb-04	70.5	30.6	68.2	53.2	52.3	65.6	68.5	74.2	84.2
13-Feb-04	67.8	25.3	55.3	38.6	23.6	52.3	38.6	38.6	38.6
20-Feb-04	58.9	20.0	62.5	23.2	12.3	21.3	23.2	23.2	23.2
25-Feb-04	75.7	5.2	61.3	12.6	1.2	2.3	12.6	12.6	12.6
29-Feb-04	80.7	-3.5	70.2	-1.3	-12.3	-3.6	-1.3	-1.3	-1.3
5-Mar-04	88.9	-31.6	56.8	-26.3	-29.3	-29.3	-26.3	-26.3	-26.3
10-Mar-04	75.2	-44.6	58.2	-40.1	-32.6	-36.2	-39.2	-42.1	-40.1
15-Mar-06	68.3	-52.3	59.0	-52.5	-48.2	-51.2	-52.3	-55.2	-53.1
20-Mar-04	58.4	-42.3	63.1	-51.3	-49.2	-47.6	-46.9	-51.3	-50.7
25-Mar-04	57.6	-40.6	59.2	-49.3	-47.9	-44.1	-45.0	-46.8	-47.4
31-Mar-04	69.4	-37.1	55.4	-47.1	-45.3	-43.9	-43.2	-45.5	-42.6
3-Apr-04	72.6	-29.0	88.3	-39.7	-39.5	-38.1	-37.7	-39.0	-35.8
4-Apr-04	68.2	-31.7	67.6	-38.8	-38.6	-35.4	-35.1	-34.1	-34.6
6-Apr-04	72.2	-27.0	81.1	-30.5	-31.2	-29.0	-28.6	-28.4	-27.0
9-Apr-04	78.1	-20.5	84.1	-23.7	-25.0	-23.6	-23.7	-23.0	-22.8
12-Apr-04	74.3	-19.1	86.8	-22.5	-24.5	-23.4	-22.4	-23.4	-22.2
16-Apr-04	77.3	-21.1	84.6	-25.1	-26.1	-24.1	-23.8	-22.9	-22.8
21-Apr-04	73.9	-18.5	87.2	-23.2	-22.2	-21.6	-23.0	-26.1	-20.9
30-Apr-04	75.6	-32.1	88.7	-34.9	-35.3	-34.5	-34.0	-35.8	-34.8
4-May-04	80.8	-27.6	88.3	-30.2	-30.1	-31.1	-28.9	-29.6	-27.5
8-May-04	72.4	-31.3	88.7	-29.7	-30.5	-28.8	-26.8	-29.5	-26.3
11-May-04	74.6	-31.9	73.2	-27.9	-29.2	-28.0	-27.3	-25.4	-24.1
14-May-04	89.1	-22.2	102.0	-27.7	-28.8	-26.8	-28.5		
18-May-04	90.9	-31.4	102.7		-21.5	-27.6	-24.0		
25-May-04	87.6	-20.8	103.2			-26.5			

Table B-30: Nitrate-N (mg/L) of 5-day HRT

					Avg. 8.28 cm ³ /cm ² /day HLR				Avg. 10.82 cm ³ /cm ² /day HLR			
Date	Day	Raw Leachate	Aerated Leachate	Distilled Water	Col. 1	Col. 2	Col. 3	Col. Avg.	Col. 1	Col. 2	Col. 3	Col. Avg.
2-Feb-04	2	2.41	3.38	4.19	2.12	2.30	1.42	1.95	1.52	1.59	0.84	1.32
5-Feb-04	5	2.20	4.03	3.57	2.78	8.21	1.87	4.29	1.86	2.26	1.49	1.87
8-Feb-04	8	2.26	11.29	2.48	4.54	4.71	2.76	4.00	2.45	1.95	1.30	1.90
13-Feb-04	13	2.52	13.98	4.17	8.18	14.98	4.71	9.29	8.18	8.18	8.18	8.18
20-Feb-04	20	3.61	17.31	3.12	15.22	23.61	16.43	18.42	15.22	15.22	15.22	15.22
25-Feb-04	25	1.83	31.43	3.28	23.33	36.93	35.33	31.86	23.33	23.33	23.33	23.33
29-Feb-04	29	1.50	44.63	2.29	40.85	63.63	44.82	49.77	40.85	40.85	40.85	40.85
5-Mar-04	34	1.08	138.51	3.93	111.87	126.25	126.25	121.46	111.87	111.87	111.87	111.87
10-Mar-04	39	1.87	233.89	3.71	195.10	144.21	166.72	168.68	188.15	211.47	195.10	198.24
15-Mar-06	44	2.47	318.99	3.60	321.57	270.41	305.16	299.04	318.99	358.53	329.44	335.65
20-Mar-04	49	3.68	213.18	3.05	306.39	281.53	263.95	283.95	256.60	306.39	299.07	287.35
25-Mar-04	54	3.80	199.07	3.57	282.66	267.16	229.22	259.68	237.69	255.57	261.83	251.70
31-Mar-04	60	2.36	172.88	4.16	258.68	240.58	227.38	242.22	221.06	242.53	215.78	226.45
3-Apr-04	63	2.08	124.73	1.10	191.98	190.44	179.99	187.47	177.11	186.64	164.06	175.93
4-Apr-04	64	2.48	139.07	2.54	185.14	183.65	161.43	176.74	159.49	153.19	156.31	156.33
6-Apr-04	66	2.11	115.07	1.48	132.50	136.30	124.73	131.18	122.74	121.75	115.07	119.85
9-Apr-04	69	1.67	88.55	1.31	100.74	106.16	100.34	102.41	100.74	97.94	97.15	98.61
12-Apr-04	72	1.94	83.70	1.17	95.99	104.04	99.53	99.85	95.60	99.53	94.83	96.66
16-Apr-04	76	1.72	90.72	1.28	106.59	110.97	102.38	106.65	101.15	97.55	97.15	98.62
21-Apr-04	81	1.97	81.70	1.15	98.73	94.83	92.57	95.38	97.94	110.97	89.99	99.64
30-Apr-04	90	1.84	141.33	1.09	158.21	160.78	155.68	158.23	152.58	164.06	157.58	158.07
4-May-04	94	1.49	117.89	1.10	130.91	130.39	135.75	132.35	124.23	127.78	117.42	123.14
8-May-04	98	2.10	136.85	1.09	128.30	132.50	123.73	128.18	114.15	127.27	111.87	117.76
11-May-04	101	1.92	140.20	2.03	119.32	125.74	119.81	121.62	116.47	107.89	102.38	108.91
14-May-04	104	1.07	94.83	0.64	118.37	123.73	114.15	118.75	122.24			122.24
18-May-04	108	0.99	137.40	0.62		92.20	117.89	105.04	101.97			101.97
25-May-04	115	1.14	89.63	0.61			112.78	112.78				
Minimum		1	3	1	2	2	1	2	2	2	1	1
Maximum		4	319	4	322	282	305	299	319	359	329	336
Median		2	115	2	118	125	118	119	113	111	107	110
Std. Dev		1	76	1	95	82	80	84	84	99	93	89
No. of Obs.		27	27	27	25	26	27	27	26	24	24	26

Table B-31 Nitrate-N Generation of Aeration Basin and Column in 5-day HRT

Date	Day	Raw Leachate	Aerated Leachate	Distilled Water	Avg. 8.28 cm ³ /cm ² /day HLR	Avg. 10.82 cm ³ /cm ² /day HLR	Generate by AB(mg/L)	Generate by Col. Avg. 8.28 cm ³ /cm ² /day HLR (mg/L)	Generate by Col. Avg. 10.82 cm ³ /cm ² /day HLR (mg/L)
					Col. Avg.	Col. Avg.			
2-Feb-04	2	2.41	3.38	4.19	1.95	1.32	0.97	-	-
5-Feb-04	5	2.20	4.03	3.57	4.29	1.87	1.83	0.26	-
8-Feb-04	8	2.26	11.29	2.48	4.00	1.90	9.03	-	-
13-Feb-04	13	2.52	13.98	4.17	9.29	8.18	11.46	-	-
20-Feb-04	20	3.61	17.31	3.12	18.42	15.22	13.70	1.11	-
25-Feb-04	25	1.83	31.43	3.28	31.86	23.33	29.60	0.43	-
29-Feb-04	29	1.50	44.63	2.29	49.77	40.85	43.14	5.13	-
5-Mar-04	34	1.08	138.51	3.93	121.46	111.87	137.43	-	-
10-Mar-04	39	1.87	233.89	3.71	168.68	198.24	232.02	-	-
15-Mar-06	44	2.47	318.99	3.60	299.04	335.65	316.52	-	16.67
20-Mar-04	49	3.68	213.18	3.05	283.95	287.35	209.50	70.77	74.17
25-Mar-04	54	3.80	199.07	3.57	259.68	251.70	195.26	60.61	52.63
31-Mar-04	60	2.36	172.88	4.16	242.22	226.45	170.52	69.34	53.57
3-Apr-04	63	2.08	124.73	1.10	187.47	175.93	122.65	62.74	51.20
4-Apr-04	64	2.48	139.07	2.54	176.74	156.33	136.59	37.67	17.26
6-Apr-04	66	2.11	115.07	1.48	131.18	119.85	112.96	16.10	4.78
9-Apr-04	69	1.67	88.55	1.31	102.41	98.61	86.89	13.86	10.06
12-Apr-04	72	1.94	83.70	1.17	99.85	96.66	81.76	16.16	12.96
16-Apr-04	76	1.72	90.72	1.28	106.65	98.62	89.00	15.93	7.90
21-Apr-04	81	1.97	81.70	1.15	95.38	99.64	79.72	13.68	17.94
30-Apr-04	90	1.84	141.33	1.09	158.23	158.07	139.49	16.90	16.74
4-May-04	94	1.49	117.89	1.10	132.35	123.14	116.40	14.46	5.25
8-May-04	98	2.10	136.85	1.09	128.18	117.76	134.75	-	-
11-May-04	101	1.92	140.20	2.03	121.62	108.91	138.28	-	-
14-May-04	104	1.07	94.83	0.64	118.75	122.24	93.76	23.91	27.41
18-May-04	108	0.99	137.40	0.62	105.04	101.97	136.40	-	-
25-May-04	115	1.14	89.63	0.61	112.78		88.50	23.15	-
Note: -sign indicates no Nitrate-N generation									
Minimum		1	3	1	2	1	1	0	5
Maximum		4	319	4	299	336	317	71	74
Median		2	115	2	119	110	113	16	17
Average		2	111	2	121	119	108	26	26
Standard Deviation		1	76	1	84	89	76	24	22
No. of Observations		27	27	27	27	26	27	18	14

Table B-32: Nitrate-N (mV) of 2-day HRT

				Avg. 8.28 cm ³ /cm ² /day HLR			Avg. 10.82 cm ³ /cm ² /day HLR		
Dated	Raw Leachate	Aerated Leachate	Distilled Water	Col. 1	Col. 2	Col. 3	Col. 1	Col. 2	Col. 3
6-Jul-04	68.9	56.2	101.3	72.1	75.8	82.1	80.3	79.3	95.1
9-Jul-04	72.1	49.9	99.9	67.2	70.9	77.8	75.0	70.5	80.8
15-Jul-04	75.0	70.8	106.1	75.1	72.0	49.0	60.4	74.4	46.4
20-Jul-04	67.7	77.2	106.5	45.3	67.8	58.9	51.9	63.6	35.2
25-Jul-04	58.5	19.8	107.6	34.3	35.4	32.6	19.9	23.4	28.2
1-Aug-04	75.7	17.5	102.5	8.3	15.4	2.3	17.5	17.4	11.4
4-Aug-04	80.7	10.5	105.2	2.3	1.4	-2.5	-6.8	-10.9	-12.9
9-Aug-04	99.0	-2.9	110.4	-32.7	-29.6	-28.8	-36.8	-30.9	-32.9
15-Aug-04	100.7	-22.6	111.4	-15.3	-12.3	-16.9	-17.4	-22.9	-22.8
24-Aug-04	76.7	12.7	103.8	-14.1	-12.4	-14.2	-20.8	-18.4	-20.9
6-Sep-04	79.7	42.0	101.3	-17.8	-18.5	-18.3	-12.6	-11.9	-12.9
14-Sep-04	83.6	48.4	103.2	-5.2		-5.1	-22.3		-22.4
24-Sep-04	87.5	88.8	102.6	-7.6		35.5	-7.3		13.5
27-Sep-04	88.9	89.1	103.2			36.7	-1.2		

Table B-33: Nitrate-N (mg/L) of 2-day HRT

					Avg. 8.28 cm ³ /cm ² /day HLR				Avg. 10.82 cm ³ /cm ² /day HLR			
Date	Day	Raw Leachate	Aerated Leachate	Distilled Water	Col. 1	Col. 2	Col. 3	Col. Avg.	Col. 1	Col. 2	Col. 3	Col. Avg.
6-Jul-04	2	2.41	4.03	0.65	2.12	1.83	1.42	1.79	1.52	1.59	0.84	1.32
9-Jul-04	5	2.12	5.19	0.69	2.58	2.23	1.69	2.17	1.89	2.26	1.49	1.88
15-Jul-04	11	1.89	2.23	0.54	1.88	2.13	5.38	3.13	3.40	1.93	5.97	3.77
20-Jul-04	16	2.53	1.73	0.53	6.25	2.52	3.61	4.13	4.79	2.99	9.38	5.72
25-Jul-04	21	3.67	17.45	0.51	9.73	9.31	10.42	9.82	17.38	15.10	12.44	14.97
1-Aug-04	28	1.83	19.15	0.62	27.74	20.84	35.33	27.97	19.15	19.23	24.48	20.95
4-Aug-04	31	1.50	25.39	0.56	35.33	36.64	42.87	38.28	50.98	60.14	65.19	58.77
9-Aug-04	36	0.72	43.57	0.45	144.79	127.78	123.73	132.10	170.80	134.66	145.96	150.47
15-Aug-04	42	0.67	96.37	0.44	71.81	63.63	76.60	70.68	78.15	97.55	97.15	90.95
24-Aug-04	51	1.76	23.23	0.59	68.42	63.89	68.70	67.00	89.63	81.37	89.99	87.00
6-Sep-04	64	1.56	7.13	0.65	79.42	81.70	81.04	80.72	64.41	62.62	65.19	64.07
14-Sep-04	72	1.33	5.51	0.61	47.80		47.61	47.70	95.22		95.60	95.41
24-Sep-04	82	1.14	1.08	0.62	52.65		9.27	30.96	52.02		22.50	37.26
27-Sep-04	85	1.08	1.07	0.61			8.83	8.83	40.68			40.68
Minimum	1	1	0	2	2	1	2	2	2	2	1	1
Maximum	4	96	1	145	128	124	132	171	135	146	150	
Median	2	6	1	35	21	23	29	46	19	24	39	
Std. Dev	1	26	0	42	42	38	39	48	46	47	45	
No. of Obs.	14	14	14	13	11	14	14	14	14	11	13	14

Table B-34: Nitrate-N Generation of Aeration Basin and Column in 2-day HRT

Date	Day	Raw Leachate	Aerated Leachate	Distilled Water	Avg. 8.28 cm ³ /cm ² /day HLR	Avg. 10.82 cm ³ /cm ² /day HLR	Generate by AB(mg/L)	Generate by Col. Avg. 8.28 cm ³ /cm ² /day HLR (mg/L)	Generate by Col. Avg. 10.82 cm ³ /cm ² /day HLR (mg/L)
					Col. Avg.	Col. Avg.			
6-Jul-04	2	2.41	4.03	0.65	1.79	1.32	1.61	-	-
9-Jul-04	5	2.12	5.19	0.69	2.17	1.88	3.07	-	-
15-Jul-04	11	1.89	2.23	0.54	3.13	3.77	0.35	0.89	1.53
20-Jul-04	16	2.53	1.73	0.53	4.13	5.72	-	2.40	3.99
25-Jul-04	21	3.67	17.45	0.51	9.82	14.97	13.78	-	-
1-Aug-04	28	1.83	19.15	0.62	27.97	20.95	17.31	8.82	1.80
4-Aug-04	31	1.50	25.39	0.56	38.28	58.77	23.89	12.89	33.38
9-Aug-04	36	0.72	43.57	0.45	132.10	150.47	42.85	88.53	106.90
15-Aug-04	42	0.67	96.37	0.44	70.68	90.95	95.71	-	-
24-Aug-04	51	1.76	23.23	0.59	67.00	87.00	21.47	43.77	63.76
6-Sep-04	64	1.56	7.13	0.65	80.72	64.07	5.57	73.59	56.94
14-Sep-04	72	1.33	5.51	0.61	47.70	95.41	4.18	42.19	89.90
24-Sep-04	82	1.14	1.08	0.62	30.96	37.26	-	29.88	36.18
27-Sep-04	85	1.08	1.07	0.61	8.83	40.68	-	7.76	39.61
Note: -sign indicates no Nitrate-N generation									
Minimum	1	1	0	2	1	0	1	2	
Maximum	4	96	1	132	150	96	89	107	
Median	2	6	1	29	39	14	21	38	
Average	2	18	1	38	48	21	31	43	
Standard Deviation	1	26	0	39	45	28	31	37	
No. of Observations	14	14	14	14	14	11	10	10	

Table B-35: Sulfide (mV) of 2-day HRT

				Avg. 8.28 cm ³ /cm ² /day HLR			Avg. 10.82 cm ³ /cm ² /day HLR		
Dated	Raw Leachate	Aerated Leachate	Distilled Water	Col. 1	Col. 2	Col. 3	Col. 1	Col. 2	Col. 3
6-Jul-04	-763.6	-694.4	-636.9	-579.6	-557.0	-553.0	-553.9	-568.9	-527.7
9-Jul-04	-753.0	-685.0	-635.0	-632.0	-632.0	-639.0	-638.0	-634.0	-639.0
15-Jul-04	-751.3	-690.2	-612.0	-635.0	-612.0	-640.0	-628.0	-625.0	-638.0
20-Jul-04	-748.0	-685.0	-612.0	-630.0	-628.0	-638.0	-629.0	-615.0	-628.0
25-Jul-04	-738.0	-689.0	-615.0	-623.0	-625.0	-638.0	-615.0	-612.0	-61.0
1-Aug-04	-736.0	-685.0	-624.0	-632.0	-632.0	-639.0	-638.0	-638.0	-629.0
4-Aug-04	-712.0	-674.0	-613.0	-635.0	-612.0	-640.0	-628.0	-638.0	-615.0
9-Aug-04	-725.0	-659.0	-581.0	-594.0	-574.0	-562.0	-585.0	-562.0	-577.0
15-Aug-04	-726.9	-648.2	-545.0	-585.1	-590.6	-596.7	-601.2	-608.9	-612.2
19-Aug-04	-735.0	-635.0	-534.0	-566.0	-545.0	-562.0	-538.0	-528.0	-551.0
24-Aug-04	-741.2	-701.9	-608.5	-570.7	-560.2	-547.9	-549.6	-547.4	-553.7
29-Aug-04	-743.0	-635.0	-583.0	-548.0	-543.0	-526.0	-541.0	-561.0	-552.0
6-Sep-04	-747.1	-649.6	-586.0	-583.0	-592.0	-572.0	-586.0	-591.0	-583.0
14-Sep-04	-757.6	-713.0	-582.0	-613.2		-613.5	-614.8		-614.5
24-Sep-04	-753.0	-656.0	-583.2	-582.0		-581.0	-548.0		-528.0
27-Sep-04	-746.0	-681.0	-546.0			-582.0	-542.0		

Table B-36: Sulfide (mg/L) of 2-day HRT

					Avg. 8.28 cm ³ /cm ² /day HLR				Avg. 10.82 cm ³ /cm ² /day HLR			
Dated	Day	Raw Leachate	Aerated Leachate	Distilled Water	Column 1	Column 2	Column 3	Column Avg.	Column 1	Column 2	Column 2	Column Avg.
6-Jul-04	2	7.025	0.209	0.011	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9-Jul-04	5	4.100	0.130	0.010	0.009	0.009	0.013	0.012	0.010	0.013	0.000	0.000
15-Jul-04	11	3.761	0.169	0.003	0.010	0.003	0.013	0.007	0.006	0.012	0.000	0.000
20-Jul-04	16	3.181	0.130	0.003	0.008	0.007	0.012	0.008	0.004	0.007	0.000	0.000
25-Jul-04	21	1.914	0.159	0.004	0.006	0.006	0.012	0.004	0.003	0.000	0.000	0.000
1-Aug-04	28	1.729	0.130	0.006	0.009	0.009	0.013	0.012	0.012	0.008	0.000	0.000
4-Aug-04	31	0.511	0.074	0.003	0.010	0.003	0.013	0.007	0.012	0.004	0.000	0.000
9-Aug-04	36	0.989	0.035	0.001	0.001	0.000	0.000	0.001	0.000	0.001	0.000	0.000
15-Aug-04	42	1.089	0.020	0.000	0.001	0.001	0.001	0.002	0.003	0.003	0.000	0.000
19-Aug-04	46	1.643	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
24-Aug-04	51	2.252	0.306	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
29-Aug-04	56	2.467	0.010	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6-Sep-04	64	3.038	0.021	0.001	0.001	0.001	0.000	0.001	0.001	0.001	0.000	0.000
14-Sep-04	72	5.180	0.537	0.001	0.003	0.000	0.003	0.004	0.000	0.004	0.000	0.000
24-Sep-04	82	4.100	0.030	0.001	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000
27-Sep-04	85	2.873	0.106	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000

Table B-37: Hydrogen Sulfide (as S) (mg/L) of 2-day HRT

Calculated the H₂S (as S) concentration for all samples using the following equations:

$$pK_1 = 32.55 + 1519.44/T - 15.672 \log_{10} T + 0.02722T$$

Where T is in °K (=°C+273)

Calculated the K_1' and $[H^+]$ for corresponding pK₁ and pH in 2-day HRT

$$K_1' = 10^{-pK_1 + 2pH}$$

$$[H^+] = 10^{-pH + pfm}$$

$$\text{Where, } pfm = A \left(\frac{\sqrt{I}}{\sqrt{I} + 1} - 0.3I \right)$$

$$A = 0.7083 - 2.277 \times 10^{-3}T + 5.399 \times 10^{-6}T^2$$

$$I = 1.6 \times 10^{-5}C$$

Where, C = Conductivity, µmhos/cm (Assumed, 700 µmhos/cm)

I = ionic strength

$$\text{Therefore, } [H_2S] = \frac{S_T}{1 + \frac{K_1'}{[H^+]}}$$

					Avg. 8.28 cm ³ /cm ² /day HLR				Avg. 10.82 cm ³ /cm ² /day HLR			
Dated	Day	Raw Leachate	Aerated Leachate	Distilled Water	Column 1	Column 2	Column 3	Column Avg.	Column 1	Column 2	Column 2	Column Avg.
6-Jul-04	2	1.884	0.004	0.010	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9-Jul-04	5	1.207	0.002	0.008	0.008	0.008	0.011	0.009	0.009	0.007	0.008	0.008
15-Jul-04	11	1.824	0.002	0.002	0.006	0.002	0.007	0.005	0.003	0.002	0.004	0.003
20-Jul-04	16	0.957	0.002	0.001	0.002	0.002	0.002	0.002	0.001	0.000	0.001	0.001
25-Jul-04	21	0.611	0.012	0.003	0.001	0.001	0.002	0.001	0.001	0.000	0.000	0.000
1-Aug-04	28	0.142	0.009	0.004	0.002	0.001	0.002	0.002	0.003	0.001	0.003	0.002
4-Aug-04	31	0.105	0.005	0.002	0.002	0.001	0.002	0.002	0.001	0.002	0.001	0.002
9-Aug-04	36	0.532	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15-Aug-04	42	0.319	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
19-Aug-04	46	0.706	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
24-Aug-04	51	0.794	0.015	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
29-Aug-04	51	0.909	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6-Sep-04	64	1.322	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14-Sep-04	72	1.132	0.021	0.000	0.000		0.001	0.001	0.000		0.001	0.001
24-Sep-04	82	1.319	0.001	0.001	0.000		0.000	0.000	0.000		0.000	0.000
27-Sep-04	85	1.055	0.006	0.000			0.000	0.000	0.000			0.000
Min		0.105	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Max		1.884	0.021	0.010	0.008	0.008	0.011	0.009	0.009	0.007	0.008	0.008
Median		0.933	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Average		0.926	0.005	0.002	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001
Std.Dev		0.526	0.006	0.003	0.002	0.002	0.003	0.002	0.002	0.002	0.002	0.002
No. of Obs		16.000	16.000	16.000	15.000	13.000	16.000	16.000	16.000	13.000	15.000	16.000

Table B-38: TSS (mg/L) of 5-day HRT

					Avg. 8.28 cm ³ /cm ² /day HLR				Avg. 10.82 cm ³ /cm ² /day HLR			
Date	Day	Raw Leachate	Aerated Leachate	Distilled Water	Col. 1	Col. 2	Col. 3	Col. Avg.	Col. 1	Col. 2	Col. 3	Col. Avg.
Feb 05,04	5	55.30	40.40	0.35	49.60	16.90	40.05	35.52	32.10	18.50	43.00	31.20
Feb 09,04	9	50.00	30.00	0.00	35.00	9.50	14.00	19.50	5.00	1.00	10.00	5.33
Feb 11,04	11	119.50	15.50	2.50	39.00	16.50	22.00	25.83	7.00	4.00	5.00	5.33
Feb 13,04	13	45.00	35.00	0.50	42.50	15.50	17.00	25.00	10.50	8.50	3.50	7.50
Feb 15,04	15	29.50	25.63	0.00	4.00	0.00	0.00	1.33	0.00	1.50	0.50	0.67
Feb 17,04	17	29.00	5.00	0.25	3.00	0.00	1.00	1.33	1.00	0.00	0.00	0.33
Feb 19,04	19	43.00	10.50	0.50	2.50	1.50	1.50	1.83	2.00	1.00	0.50	1.17
Feb 21,04	21	20.50	6.00	0.00	0.50	0.00	0.50	0.33	1.00	1.50	0.00	0.83
Feb 23,04	23	31.50	7.00	0.00	8.00	2.00	0.50	3.50	1.00	2.00	0.50	1.17
Feb 25,04	25	16.50	9.50	0.50	2.50	4.00	2.00	2.83	0.50	1.00	2.00	1.17
Feb 27,04	27	34.00	9.00	0.00	3.00	3.50	0.50	2.33	1.50	2.50	3.50	2.50
Feb 29,04	29	32.00	8.50	0.50	1.50	6.00	4.50	4.00	3.00	2.00	3.50	2.83
March 02,04	31	27.00	10.00	2.00	0.00	0.50	0.50	0.33	0.00	2.00	2.00	1.33
March 04,04	33	30.00	11.00	0.00	4.50	1.00	1.50	2.33	1.00	0.50	0.00	0.50
March 07,04	36	26.50	11.50	1.00	2.00	5.50	3.00	3.50	0.50	1.50	2.50	1.50
March 10,04	39	57.50	4.00	0.00	14.00	7.00	9.50	10.17	15.00	5.00	11.50	10.50
March 13,04	42	36.00	8.00	0.50	6.50	2.00	10.50	6.33	6.00	2.00	2.50	3.50
March 16,04	45	27.50	9.50	0.00	3.00	1.00	7.50	3.83	2.50	3.50	1.50	2.50
March 19,04	48	33.00	6.00	0.00	6.50	1.50	16.00	8.00	6.00	2.50	1.50	3.33
March 22,04	51	28.00	9.50	0.50	16.50	1.00	8.00	8.50	11.50	0.50	2.00	4.67
March 25,04	54	10.50	7.50	0.00	5.00	1.00	10.00	5.33	3.00	3.00	4.00	3.33
April 10,04	70	34.00	123.00	0.00	0.00	10.00	0.00	3.33	13.00	9.00	14.00	12.00
April 21,04	81	34.00	170.00	0.00	0.00	10.00	0.00	3.33	13.00	9.00	14.00	12.00
April 24,04	84	174.20	161.10	0.00	11.30	11.70	11.60	11.53	13.10	12.10	12.50	12.57
April 27,04	87	96.00	359.00	0.00	11.90	10.80	10.00	10.90	14.80	11.80	7.50	11.37
May 04,04	94	130.60	295.10	0.00	18.30	17.30	14.50	16.70	20.10	21.10	15.20	18.80
May 11,04	101	113.40	317.10	0.00	17.50	16.00	14.70	16.07	16.80	19.50	13.40	16.57
Minimum		11	4	0				0				0
Maximum		174	359	3				36				31
Average		51	63	0				9				6
Std. Dev		40	105	1				9				7
No. of Obs.		27	27	21				27				27

Table B-39: Cumulative TSS Influent & Removal of Peat Columns in 5-day HRT

Wt. of Peat (Avg. 8.28 cm³/cm²/day) = ((975+810+975)/3)*(1-0.5104)=450.432 g of peat

Wt. of Peat (Avg. 10.82 cm³/cm²/day) = ((1020+775+970)/3)*(1-0.5104)=451.248 g of peat

Day	Day Interval	Aerated Leachate	Flow (mL/d) Avg. 8.28	Flow (mL/d) Avg. 10.82	Inf. TSS (mg/g-d) Avg. 8.28	Cum TSS Inf. (mg/g) Avg. 8.28	Inf. TSS (mg/g-d) Avg. 10.82	Cum TSS Inf. (mg/g) Avg. 10.82	TSS (mg/L) Avg. 8.28	TSS (mg/L) Avg. 10.82	TSS Removal Avg. 8.28	Cum TSS Removal Avg. 8.28	TSS Removal Avg. 10.82	Cum TSS Removal Avg. 10.82
5	5	40.40	652.33	845.67	0.06	0.29	0.08	0.38	35.52	31.20	0.01	0.04	0.02	0.09
9	4	30.00	639.67	862.17	0.04	0.46	0.06	0.61	19.50	5.33	0.01	0.09	0.05	0.27
11	2	15.50	628.00	843.33	0.02	0.51	0.03	0.67	25.83	5.33	-0.01	0.07	0.02	0.31
13	2	35.00	630.50	854.17	0.05	0.60	0.07	0.80	25.00	7.50	0.01	0.09	0.05	0.42
15	2	25.63	633.00	865.00	0.04	0.68	0.05	0.90	1.33	0.67	0.03	0.16	0.05	0.51
17	2	5.00	623.25	840.58	0.01	0.69	0.01	0.92	1.33	0.33	0.01	0.17	0.01	0.53
19	2	10.50	613.75	845.08	0.01	0.72	0.02	0.95	1.83	1.17	0.01	0.20	0.02	0.56
21	2	6.00	613.34	833.17	0.01	0.73	0.01	0.98	0.33	0.83	0.01	0.21	0.01	0.58
23	2	7.00	620.67	825.50	0.01	0.75	0.01	1.00	3.50	1.17	0.00	0.22	0.01	0.61
25	2	9.50	614.34	807.84	0.01	0.78	0.02	1.04	2.83	1.17	0.01	0.24	0.01	0.64
27	2	9.00	609.17	794.84	0.01	0.80	0.02	1.07	2.33	2.50	0.01	0.26	0.01	0.66
29	2	8.50	615.00	799.34	0.01	0.83	0.02	1.10	4.00	2.83	0.01	0.27	0.01	0.68
31	2	10.00	618.34	790.22	0.01	0.86	0.02	1.13	0.33	1.33	0.01	0.30	0.02	0.71
33	2	11.00	621.67	785.33	0.02	0.89	0.02	1.17	2.33	0.50	0.01	0.32	0.02	0.75
36	3	11.50	607.33	794.67	0.02	0.93	0.02	1.23	3.50	1.50	0.01	0.35	0.02	0.80
39	3	4.00	595.67	784.00	0.01	0.95	0.01	1.25	10.17	10.50	-0.01	0.33	-0.01	0.76
42	3	8.00	564.00	737.67	0.01	0.98	0.01	1.29	6.33	3.50	0.00	0.33	0.01	0.79
45	3	9.50	573.00	764.34	0.01	1.01	0.02	1.34	3.83	2.50	0.01	0.36	0.01	0.82
48	3	6.00	583.00	791.00	0.01	1.04	0.01	1.37	8.00	3.33	0.00	0.35	0.00	0.84
51	3	9.50	582.67	755.00	0.01	1.07	0.02	1.42	8.50	4.67	0.00	0.35	0.01	0.86
54	3	7.50	572.33	779.67	0.01	1.10	0.01	1.46	5.33	3.33	0.00	0.36	0.01	0.88
70	16	123.00	569.77	791.44	0.16	3.59	0.22	4.91	3.33	12.00	0.15	2.78	0.19	4.00
81	11	170.00	553.33	745.67	0.21	5.89	0.28	8.00	3.33	12.00	0.20	5.03	0.26	6.87
84	3	161.00	538.33	731.00	0.19	6.47	0.26	8.78	11.53	12.57	0.18	5.57	0.24	7.59
87	3	359.00	541.67	757.67	0.43	7.76	0.60	10.59	10.90	11.37	0.42	6.83	0.58	9.34
94	7	295.10	572.00	714.33	0.37	10.39	0.47	13.86	16.70	18.80	0.35	9.30	0.44	12.40
101	7	317.10	502.67	483.00	0.35	12.86	0.34	16.24	16.07	16.57	0.34	11.65	0.32	14.65

Table B-40: TSS (mg/L) of 2-day HRT

					Avg. 8.28 cm ³ /cm ² /day HLR				Avg. 10.82 cm ³ /cm ² /day HLR			
Date	Day	Raw Leachate	Aerated Leachate	Distilled Water	Col. 1	Col. 2	Col. 3	Col. Avg.	Col. 1	Col. 2	Col. 3	Col. Avg.
6-Jul-04	2	147.00	28.00	0	14.00	7.00	13.00	11.33	9.00	38.00	33.00	26.67
20-Jul-04	16	127.00	58.00	1.00	31.00	20.00	30.00	27.00	23.00	22.00	45.00	30.00
25-Jul-04	21	151.00	120.00	0.00	61.00	50.00	71.00	60.67	81.00	73.00	74.00	76.00
4-Aug-04	31	163.00	31.00	1.00	21.00	25.00	33.00	26.33	40.00	63.00	60.00	54.33
9-Aug-04	36	148.00	15.00	1.00	21.30	56.00	7.00	28.10	14.00	18.00	21.00	17.67
15-Aug-04	42	88.00	60.00	0	20.00	41.00	22.00	27.67	27.00	45.00	15.00	29.00
24-Aug-04	51	123.00	71.00	4.00	40.00	25.00	27.00	30.67	51.00	41.00	38.00	43.33
6-Sep-04	64	118.00	107.00	5.00	21.00	52.00	29.00	34.00	59.00	27.00	47.00	44.33
14-Sep-04	72	117.00	93.00	2.00	36.00		36.00	36.00	38.00		50.00	44.00
20-Sep-04	78	143.00	150.00	3.00	35.00		41.00	38.00	60.00		75.00	67.50
24-Sep-04	82	124.00	194.00	2.00	34.00		53.00	43.50	38.00		31.00	34.50
27-Sep-04	85	166.00	204.00	0.00			41.00	41.00	35.00			
Minimum		88	15	0				11				18
Maximum		166	204	5				61				76
Average		135	94	2				34				42
Std. Dev		22	63	2				12				18
No. of Obs.		12	12	10				12				11

Table B-41: Cumulative TSS Influent & Removal of Peat Columns in 2-day HRTWt. of Peat (Avg. 8.28 cm³/cm²/day) = 850*(1-0.1421)=729.215 g of peatWt. of Peat (Avg. 10.82 cm³/cm²/day) = 850*(1-0.1421)=729.215 g of peat

Day	Day Interval	Aerated Leachate	Flow (mL/d) Avg. 8.28	Flow (mL/d) Avg. 10.82	Inf. TSS (mg/g-d) Avg. 8.28	Cum TSS Inf. (mg/g) Avg. 8.28	Inf. TSS (mg/g-d) Avg. 10.82	Cum TSS Inf. (mg/g) Avg. 10.82	TSS (mg/L) Avg. 8.28	TSS (mg/L) Avg. 10.82	TSS Removal Avg. 8.28	Cum TSS Removal Avg. 8.28	TSS Removal Avg. 10.82	Cum TSS Removal Avg. 10.82
2	2	28.00	587.33	818.33	0.02	0.05	0.03	0.06	11.33	26.67	0.01	0.03	0.00	0.00
16	14	58.00	592.33	825.67	0.05	0.70	0.07	0.98	27.00	30.00	0.03	0.38	0.03	0.45
21	5	120.00	580.67	823.67	0.10	1.18	0.14	1.66	60.67	76.00	0.05	0.62	0.05	0.70
31	10	31.00	561.00	826.00	0.02	1.42	0.04	2.01	26.33	54.33	0.00	0.65	-0.03	0.43
36	5	15.00	567.33	816.67	0.01	1.48	0.02	2.10	28.10	17.67	-0.01	0.60	0.00	0.42
42	6	60.00	573.00	818.00	0.05	1.76	0.07	2.50	27.67	29.00	0.03	0.75	0.03	0.62
51	9	71.00	556.00	829.67	0.05	2.25	0.08	3.23	30.67	43.33	0.03	1.03	0.03	0.91
64	13	107.00	506.33	679.33	0.07	3.22	0.10	4.52	34.00	44.33	0.05	1.69	0.06	1.67
72	8	93.00	550.00	835.00	0.07	3.78	0.11	5.37	36.00	44.00	0.04	2.03	0.06	2.12
78	6	150.00	550.00	825.00	0.11	4.46	0.17	6.39	38.00	67.50	0.08	2.54	0.09	2.68
82	4	194.00	470.50	781.50	0.13	4.96	0.21	7.22	43.50	34.50	0.10	2.93	0.17	3.36
85	3	204.00	538.00	770.00	0.15	5.41	0.22	7.87	41.00		0.12	3.29		

Table B-42: Boron (mg/L) of 2-day HRT

					Avg. 8.28 cm ³ /cm ² /day HLR				Avg. 10.82 cm ³ /cm ² /day HLR			
Dated	Day	Raw Leachate	Aerated Leachate	Distilled Water	Col. 1	Col. 2	Col. 3	Col Avg.	Col. 1	Col. 2	Col. 3	Col Avg.
06-Jul-04	2	6.355	6.162	0.238	0.314	0.359	0.303	0.325	0.277	0.247	0.371	0.298
12-Jul-04	8	5.825	5.888	0.112	0.289	0.221	0.248	0.253	0.187	0.162	0.151	0.167
20-Jul-04	16	6.136	6.486	0.170	0.259	0.164	0.198	0.207	1.769	0.705	6.264	2.912
26-Jul-04	22	6.201	6.285	0.163	4.886	0.264	4.987	3.379	8.392	3.591	7.675	6.553
01-Aug-04	28	4.889	5.810	0.200	4.498	2.598	7.412	4.836	6.564	7.568	7.412	7.181
09-Aug-04	36	2.440	4.073	0.169	3.005	5.541	5.253	4.600	4.284	5.994	5.541	5.273
15-Aug-04	42	4.311	4.412	0.196	5.174	5.587	5.619	5.460	3.823	6.026	5.751	5.200
24-Aug-04	51	5.738	5.333	0.186	5.052	5.288	4.756	5.032	4.147	4.559	6.988	5.231
06-Sep-04	64	6.371	6.277	0.159	4.911	3.654	5.807	4.791	6.651	4.889	2.466	4.669
24-Sep-04	82	5.942	6.172		7.652		5.516	6.584	7.570		7.324	7.447
Min		2.44	4.07	0.11	0.26	0.16	0.20	0.21	0.19	0.16	0.15	0.17
Max		6.37	6.49	0.24	7.65	5.59	7.41	6.58	8.39	7.57	7.67	7.45
Median		5.88	6.03	0.17	4.69	2.60	5.12	4.70	4.22	4.56	6.01	5.22
Average		5.42	5.69	0.18	3.60	2.63	4.01	3.55	4.37	3.75	4.99	4.49
Std. Dev.		1.24	0.83	0.03	2.55	2.45	2.69	2.40	2.94	2.77	2.91	2.60
No. of Obs.		10.00	10.00	9.00	10.00	9.00	10.00	10.00	10.00	9.00	10.00	10.00

Table B-43: Summary of Boron Break Through of Peat Columns in 2-day HRT

Phase	Column ID	Break Through Observed (day)	Cumulative Boron Removal (mg/ g of Peat)
2-day HRT	Controlled Column(DW)	-	-
	Avg. 8.28 cm ³ /cm ² /day	Column 1	0.100
		Column 2	0.118
		Column 3	0.085
	Avg. 10.82 cm ³ /cm ² /day	Column 1	0.096
		Column 2	0.122
		Column 3	0.054

Table B-44: Boron Break Through of Peat Column 1 in 2-day HRT

Wt. of Peat (Avg. 8.28 cm³/cm²/day) = 850*(1-0.1421)=729.215 g of peat
Wt. of Peat (Avg. 10.82 cm³/cm²/day) = 850*(1-0.1421)=729.215 g of peat

Day	Day Interval	Aerated Leachate	Flow(mL/d) Avg. 8.28	Flow(mL/d) Avg. 10.82	COD(mg/L) Avg.8.28	COD(mg/L) Avg.10.82	COD Removal Avg.8.28	Cum Removal 8.28	COD Removal Avg.10.82	Cum Removal 10.82
2	2	6.162	611.000	815.000	0.314	0.277	0.005	0.010	0.007	0.013
8	6	5.888	623.000	846.500	0.289	0.187	0.005	0.039	0.007	0.053
16	8	6.486	610.000	824.000	0.259	1.769	0.005	0.080	0.005	0.096
22	6	6.285	584.000	814.000	4.886	8.392	0.001	0.087	-0.002	
28	6	5.810	563.000	818.000	4.498		0.001	0.093		
36	8	4.073	572.000	815.000	3.005		0.001	0.100		
42	6	4.412	576.000	812.000	5.174		-0.001			
51	9	5.333	558.000	821.000						
64	13	6.277	535.000	824.000						

Table B-45: Boron Break Through of Peat Column 2 in 2-day HRTWt. of Peat (Avg. 8.28 cm³/cm²/day) = 850*(1-0.1421)=729.215 g of peatWt. of Peat (Avg. 10.82 cm³/cm²/day) = 850*(1-0.1421)=729.215 g of peat

Day	Day Interval	Aerated Leachate	Flow(mL/d) Avg. 8.28	Flow(mL/d) Avg. 10.82	COD(mg/L) Avg.8.28	COD(mg/L) Avg.10.82	COD Removal Avg.8.28	Cum Removal 8.28	COD Removal Avg.10.82	Cum Removal 10.82
2	2	6.162	528.000	780.000	0.359	0.247	0.004	0.008	0.006	0.013
8	6	5.888	581.000	832.000	0.221	0.162	0.005	0.035	0.007	0.052
16	8	6.486	578.000	818.000	0.164	0.705	0.005	0.076	0.006	0.104
22	6	6.285	571.000	812.000	0.264	3.591	0.005	0.104	0.003	0.122
28	6	5.810	550.000	814.000	2.598	7.568	0.002	0.118	-0.002	
36	8	4.073	536.000	791.000	5.541		-0.001			
42	6	4.412	556.000	800.000						
51	9	5.333	542.000	812.000						
64	13	6.277	393.000	340.000						

Table B-46: Boron Break Through of Peat Column 3 in 2-day HRTWt. of Peat (Avg. 8.28 cm³/cm²/day) = 850*(1-0.1421)=729.215 g of peatWt. of Peat (Avg. 10.82 cm³/cm²/day) = 850*(1-0.1421)=729.215 g of peat

Day	Day Interval	Aerated Leachate	Flow(mL/d) Avg. 8.28	Flow(mL/d) Avg. 10.82	COD(mg/L) Avg.8.28	COD(mg/L) Avg.10.82	COD Removal Avg.8.28	Cum Removal 8.28	COD Removal Avg.10.82	Cum Removal 10.82
2	2	6.162	623.000	860.000	0.303	0.371	0.005	0.010	0.007	0.014
8	6	5.888	604.000	822.000	0.248	0.151	0.005	0.038	0.006	0.052
16	8	6.486	589.000	835.000	0.198	6.264	0.005	0.079	0.000	0.054
22	6	6.285	587.000	845.000	4.987	7.675	0.001	0.085	-0.002	
28	6	5.810	580.500	847.000	7.412		-0.001			
36	8	4.073	594.000	844.000						
42	6	4.412	587.000	842.000						
51	9	5.333	568.000	856.000						
64	13	6.277	591.000	874.000						

B Break Through Observed (day)**2-day HRT**

Column ID	Avg. 8.28 cm3/cm2/day	Avg. 10.82 cm3/cm2/day
Column 1	42	22
Column 2	36	28
Column 3	28	22

Anova: Single
Factor

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
Column 1	3	106	35.33333333	49.33333
Column 2	3	72	24	12

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	192.6667	1	192.6666667	6.282609	0.066304	7.70865
Within Groups	122.6667	4	30.66666667			
Total	315.3333	5				

Cumulative Boron Removal (mg/ g of Peat)**2-day HRT**

Column ID	Avg. 8.28 cm3/cm2/day	Avg. 10.82 cm3/cm2/day
Column 1	0.100	0.096
Column 2	0.118	0.122
Column 3	0.085	0.054

Anova: Single
Factor

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
Column 1	3	0.303	0.101	0.000273
Column 2	3	0.272	0.090666667	0.001177

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	0.00016	1	0.000160167	0.220869	0.662856	7.70865
Within Groups	0.002901	4	0.000725167			
Total	0.003061	5				

Table B-47: Barium (mg/L) of 2-day HRT

Dated	Day	Raw Leachate	Aerated Leachate	Distilled Water	Avg. 8.28 cm ³ /cm ² /day HLR				Avg. 10.82 cm ³ /cm ² /day HLR			
					Col. 1	Col. 2	Col. 3	Col. Avg.	Col. 1	Col. 2	Col. 3	Col. Avg.
06-Jul-04	2	0.136	0.055	0.015	0.039	0.031	0.037	0.036	0.073	0.055	0.058	0.062
12-Jul-04	8	0.618	0.187	0.006	0.146	0.157	0.145	0.149	0.092	0.091	0.084	0.089
20-Jul-04	16	1.166	0.610	0.005	0.066	0.061	0.056	0.061	0.053	0.055	0.052	0.053
26-Jul-04	22	0.822	1.176	0.005	0.039	0.040	0.036	0.038	0.037	0.038	0.078	0.051
01-Aug-04	28	0.845	1.845	0.005	0.030	0.028	0.039	0.032	0.041	0.035	0.091	0.056
09-Aug-04	36	0.935	1.673	0.005	0.069	0.022	0.086	0.059	0.092	0.070	0.083	0.082
15-Aug-04	42	0.718	0.773	0.004	0.041	0.011	0.046	0.033	0.048	0.044	0.045	0.046
24-Aug-04	51	1.002	1.200	0.005	0.061	0.012	0.069	0.047	0.080	0.075	0.077	0.077
06-Sep-04	64	0.964	0.378	0.005	0.089	0.027	0.088	0.068	0.073	0.031	0.056	0.053
24-Sep-04	82	1.377	1.091				0.081	0.081	0.072			0.072
Min		0.14	0.06	0.00	0.03	0.01	0.04	0.03	0.04	0.03	0.05	0.05
Max		1.38	1.85	0.02	0.15	0.16	0.15	0.15	0.09	0.09	0.09	0.09
Median		0.89	0.93	0.01	0.06	0.03	0.06	0.05	0.07	0.06	0.08	0.06
Average		0.86	0.90	0.01	0.06	0.04	0.07	0.06	0.07	0.05	0.07	0.06
Std. Dev.		0.33	0.60	0.00	0.04	0.05	0.03	0.04	0.02	0.02	0.02	0.01
No. of Obs.		10.00	10.00	9.00	9.00	9.00	10.00	10.00	10.00	9.00	9.00	10.00

Table B-48: Barium Removal of Aeration Basin and Column in 2-day HRT

Dated	Day	Raw Leachate	Aerated Leachate	Distilled Water	Avg. 8.28 cm ³ /cm ² /day HLR	Avg. 10.82 cm ³ /cm ² /day HLR	% Removal by Aeration Basin	% Removal by 8.28 cm ³ /cm ² /day HLR (Col. Avg.)	% Removal by 10.82 cm ³ /cm ² /day HLR (Col. Avg.)
					Col. Avg.	Col. Avg.			
06-Jul-04	2	0.136	0.055	0.015	0.036	0.062	59.56	35.15	-
12-Jul-04	8	0.618	0.187	0.006	0.149	0.089	69.74	20.14	52.41
20-Jul-04	16	1.166	0.610	0.005	0.061	0.053	47.68	90.00	91.26
26-Jul-04	22	0.822	1.176	0.005	0.038	0.051	-	96.74	95.66
01-Aug-04	28	0.845	1.845	0.005	0.032	0.056	-	98.25	96.98
09-Aug-04	36	0.935	1.673	0.005	0.059	0.082	-	96.47	95.12
15-Aug-04	42	0.718	0.773	0.004	0.033	0.046	-	95.77	94.09
24-Aug-04	51	1.002	1.200	0.005	0.047	0.077	-	96.06	93.56
06-Sep-04	64	0.964	0.378	0.005	0.068	0.053	60.79	82.01	85.89
24-Sep-04	82	1.377	1.091		0.081	0.072	20.77	92.58	93.40
Note: - Sign indicates no removal of Barium									
Minimum		0.14	0.06	0.00	0.03	0.05	21	20	52
Maximum		1.38	1.85	0.02	0.15	0.09	70	98	97
Median		0.89	0.93	0.01	0.05	0.06	60	94	94
Average		0.86	0.90	0.01	0.06	0.06	52	80	89
Standard Deviation		0.33	0.60	0.00	0.04	0.01	19	28	14
No. of Observations		10.00	10.00	9.00	10.00	10.00	5	10	9

Table B-49: pH of Raw, Aerated and Column Effluents in 5-day HRT

Date	Day	Raw Leachate	Aerated Leachate	Distilled Water	Avg. 8.28 cm ³ /cm ² /day HLR				Avg. 10.82 cm ³ /cm ² /day HLR			
					Column 1	Column 2	Column 3	Column Avg.	Column 1	Column 2	Column 3	Column Avg.
2-Feb-04	2	7.60	8.91	6.36	6.41	6.24	6.05	6.23	6.28	5.98	6.54	6.27
3-Feb-04	3	7.56	8.89	6.44	6.56	5.99	6.41	6.32	6.58	6.24	6.8	6.54
4-Feb-04	4	7.46	8.88	6.60	6.81	6.26	6.66	6.58	6.82	6.74	6.99	6.85
5-Feb-04	5	7.50	8.87	5.88	6.95	6.61	6.83	6.80	6.95	6.97	7.18	7.03
9-Feb-04	9	7.82	8.89	6.35	7.22	7.09	7.09	7.13	7.22	7.29	7.64	7.38
11-Feb-04	11	7.75	8.86	6.43	7.65	7.57	7.55	7.59	7.89	7.67	7.6	7.72
15-Feb-04	15	7.59	7.25	7.27	7.68	7.54	7.67	7.63	7.66	7.48	7.82	7.65
16-Feb-04	16	7.75	7.22	6.58	7.61	7.22	7.37	7.40	7.6	7.43	7.8	7.61
20-Feb-04	20	7.71	8.06	6.54	7.6	7.48	7.57	7.55	7.81	7.57	7.84	7.74
22-Feb-04	22	7.25	8.14	6.68	7.87	7.75	7.84	7.82	8.01	7.76	7.96	7.91
24-Feb-04	24	7.63	8.32	6.67	7.75	7.64	7.76	7.72	7.88	7.57	7.88	7.78
26-Feb-04	26	7.13	8.25	6.62	7.75	7.61	7.77	7.71	7.84	7.52	7.88	7.75
28-Feb-04	28	7.46	8.07	6.44	7.8	7.59	7.94	7.78	7.93	7.58	7.92	7.81
1-Mar-04	30	7.29	8.32	6.50	7.71	7.44	7.83	7.66	7.84	7.43	7.92	7.73
4-Mar-04	33	8.19	8.23	6.37	7.73	7.33	7.79	7.62	7.86	7.33	7.96	7.72
7-Mar-04	36	7.23	7.94	6.87	7.92	7.65	8.02	7.86	8.04	7.48	7.95	7.82
10-Mar-04	39	7.39	8.38	6.83	7.8	7.28	7.81	7.63	7.87	7.37	7.89	7.71
13-Mar-04	42	7.25	8.10	7.00	7.75	7.35	7.72	7.61	7.92	7.42	7.79	7.71
16-Mar-04	45	7.73	8.12	7.07	7.73	7.54	7.78	7.68	7.81	7.44	7.79	7.68
19-Mar-04	48	8.00	8.36	6.70	7.68	7.34	7.74	7.59	7.85	7.39	7.71	7.65
22-Mar-04	51	7.60	7.93	6.71	7.86	7.57	7.87	7.77	7.92	7.53	7.81	7.75
25-Mar-04	54	7.41	7.79	7.43	7.88	7.65	7.89	7.81	7.93	7.44	7.73	7.70
28-Mar-04	57	7.21	8.13	6.98	7.45	7.25	7.57	7.42	7.62	7.27	7.5	7.46
31-Mar-04	60	6.90	8.33	7.00	7.75	7.52	7.86	7.71	7.92	7.57	7.84	7.78
3-Apr-04	63	6.99	8.30	7.03	7.85	7.66	7.94	7.82	7.97	7.68	7.86	7.84
4-Apr-04	64	7.02	8.26	6.89	7.88	7.61	7.95	7.81	7.98	7.65	7.84	7.82
6-Apr-04	66	6.78	8.25	6.74	7.84	7.57	7.92	7.78	7.9	7.6	7.76	7.75
9-Apr-04	69	7.55	8.31	6.59	7.82	7.5	7.86	7.73	7.92	7.46	7.64	7.67
12-Apr-04	72	6.85	8.31	6.30	7.74	7.47	7.78	7.66	7.86	7.53	7.63	7.67
15-Apr-04	75	6.87	8.25	6.44	7.76	7.59	7.94	7.76	7.88	7.58	7.81	7.76
18-Apr-04	78	6.92	8.21	6.51	7.81	7.62	7.86	7.76	7.87	7.61	7.83	7.77
21-Apr-04	81	6.97	8.19	6.61	7.8	7.68	7.82	7.77	7.89	7.69	7.78	7.79
24-Apr-04	84	7.08	8.25	6.68	7.92	7.72	7.86	7.83	7.93	7.72	7.79	7.81
27-Apr-04	87	7.05	8.19	6.76	7.92	7.75	7.87	7.85	7.93	7.7	7.78	7.80
30-Apr-04	90	6.91	8.04	6.77	7.74	7.63	7.73	7.70	7.82	7.61	7.69	7.71
4-May-04	94	6.92	8.10	6.47	7.83	7.86	7.75	7.81	7.96	7.71	7.72	7.80
8-May-04	98	7.66	8.16	6.69	7.92	7.79	7.88	7.86	7.97	7.71	7.69	7.79
11-May-04	101	7.62	7.82	7.06	8.18	8.05	7.94	8.06	7.93	7.58	7.92	7.81
14-May-04	104	7.47	8.38	6.77	8.28	7.89	8.02	8.06	8.2	*	*	8.20
18-May-04	108	7.31	8.14	7.00	*	8.04	8.11	8.08	8.28	*	*	8.28
Minimum		6.78	7.22	5.88	6.41	5.99	6.05	6.23	6.28	5.98	6.54	6.27
Maximum		8.19	8.91	7.43	8.28	8.05	8.11	8.08	8.28	7.76	7.96	8.28
Median		7.40	8.24	6.68	7.75	7.57	7.82	7.71	7.89	7.53	7.79	7.74
Std. Dev		0.35	0.37	0.29	0.38	0.45	0.45	0.42	0.41	0.37	0.31	0.37
No. of Obs.		40	40	40	39	40	40	40	40	38	38	40

Table B-50: pH of Raw, Aerated and Column Effluents in 2-day HRT

					Avg. 8.28 cm ³ /cm ² /day HLR				Avg. 10.82 cm ³ /cm ² /day HLR			
Date	Day	Raw Leachate	Aerated Leachate	Distilled Water	Column 1	Column 2	Column 3	Column Avg.	Column 1	Column 2	Column 3	Column Avg.
6-Jul-04	2	7.44	8.77	6.15	6.17	6.36	6.17	6.23	6.00	5.86	5.91	5.92
9-Jul-04	5	7.37	8.93	6.43	5.99	6.13	6.15	6.09	6.58	6.52	6.81	6.64
15-Jul-04	11	7.03	8.85	6.71	6.90	6.77	6.99	6.89	7.10	7.27	7.33	7.23
20-Jul-04	16	7.37	8.89	7.11	7.46	7.55	7.66	7.56	7.64	7.87	7.69	7.73
25-Jul-04	21	7.34	8.12	6.54	7.72	7.56	7.85	7.71	7.75	7.94	7.42	7.70
1-Aug-04	28	8.04	8.16	6.77	7.67	7.77	7.72	7.72	7.42	7.89	7.31	7.54
4-Aug-04	31	7.59	8.18	6.65	7.68	7.66	7.67	7.67	7.66	7.68	7.35	7.56
9-Aug-04	36	6.94	8.24	6.77	7.39	7.85	7.49	7.58	7.37	7.69	7.39	7.48
15-Aug-04	42	7.36	8.11	7.00	7.64	8.14	7.64	7.81	7.50	7.72	7.42	7.55
19-Aug-04	46	7.08	8.14	6.89	7.68	7.89	7.55	7.71	7.48	7.76	7.32	7.52
24-Aug-04	51	7.23	8.27	7.00	7.43	8.04	7.41	7.63	7.23	7.45	7.23	7.30
29-Aug-04	56	7.20	8.26	7.02	7.51	7.75	7.42	7.56	7.31	7.69	7.39	7.46
6-Sep-04	64	7.09	8.25	6.99	7.54	7.69	7.44	7.56	7.42	8.01	7.49	7.64
14-Sep-04	72	7.51	8.36	6.98	7.85		7.43	7.64	8.11		7.48	7.80
24-Sep-04	82	7.29	8.32	6.50	7.71		7.83	7.77	7.84		7.92	7.88
27-Sep-04	85	7.20	8.23	6.37			7.79	7.79	7.86			7.86
5-Oct-04	93	7.23	8.31	6.87			8.02	8.02	8.04			8.04
Minimum		6.94	8.11	6.15	5.99	6.13	6.15	6.09	6.00	5.86	5.91	5.92
Maximum		8.04	8.93	7.11	7.85	8.14	8.02	8.02	8.11	8.01	7.92	8.04
Median		7.29	8.26	6.77	7.54	7.69	7.55	7.64	7.48	7.69	7.39	7.55
Std. Dev		0.25	0.29	0.27	0.56	0.64	0.53	0.54	0.52	0.62	0.45	0.51
No. of Obs.		17	17	17	15	13	17	17	17	13	15	17

Table B-51: Temperature of Raw, Aerated and Column Effluents in 5-day HRT

					Avg. 8.28 cm ³ /cm ² /day HLR				Avg. 10.82 cm ³ /cm ² /day HLR			
Date	Day	Raw Leachate	Aerated Leachate	Distilled Water	Column 1	Column 2	Column 3	Column Avg.	Column 1	Column 2	Column 3	Column Avg.
2-Feb-04	2	23.00	22.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00
3-Feb-04	3	24.00	22.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00
4-Feb-04	4	23.00	22.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00
5-Feb-04	5	23.00	22.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00
6-Feb-04	6	23.00	22.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00
9-Feb-04	9	23.00	21.50	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00
11-Feb-04	11	22.50	22.00	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50
13-Feb-04	13	23.00	22.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00
15-Feb-04	15	23.00	22.00	23.50	23.50	23.50	23.50	23.50	23.00	23.20	23.00	23.07
16-Feb-04	16	22.50	22.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00
20-Feb-04	20	23.00	22.00	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50
22-Feb-04	22	23.00	22.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50
24-Feb-04	24	23.00	22.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00
26-Feb-04	26	23.00	22.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50
28-Feb-04	28	23.00	22.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50
1-Mar-04	30	23.00	22.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50
4-Mar-04	33	22.50	22.00	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50
7-Mar-04	36	23.00	22.00	23.20	23.00	23.20	23.20	23.13	23.20	23.20	23.20	23.20
10-Mar-04	39	23.00	22.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50
13-Mar-04	42	23.00	22.00	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50
16-Mar-04	45	23.00	22.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50
19-Mar-04	48	23.50	22.50	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90	23.90
22-Mar-04	51	23.00	22.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00
25-Mar-04	54	23.00	22.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50
28-Mar-04	57	23.00	22.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50
31-Mar-04	60	23.00	21.90	22.80	22.80	22.80	22.80	22.80	22.80	22.80	22.80	22.80
3-Apr-04	63	22.50	22.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00
4-Apr-04	64	22.50	22.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00
6-Apr-04	66	22.50	22.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00
9-Apr-04	69	22.50	22.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00
12-Apr-04	72	23.00	22.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00
24-Apr-04	84	21.50	20.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50
27-Apr-04	87	22.00	21.50	22.50	22.50	22.50	22.50	22.50	22.50	22.50	22.50	22.50
30-Apr-04	90	23.50	23.00	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50
4-May-04	94	20.40	20.50	22.50	22.50	22.50	22.50	22.50	22.50	22.50	22.50	22.50
8-May-04	98	20.50	19.50	20.50	20.50	20.50	20.50	20.50	20.50	20.50	20.50	20.50
11-May-04	101	22.00	21.50	22.50	22.50	22.50	22.50	22.50	22.50	22.50	22.50	22.50
14-May-04	104	23.50	23.00	24.50	24.50	24.50	24.50	24.50	24.50			24.50
18-May-04	108	23.50	23.00	24.50		24.50	24.50	24.50	24.50			24.50
25-May-04	115	23.50	23.00	24.50			24.50	24.50				
Minimum		20.40	19.50	20.50	20.50	20.50	20.50	20.50	20.50	20.50	20.50	20.50
Maximum		24.00	23.00	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50
Median		23.00	22.00	23.50	23.25	23.50	23.50	23.50	23.20	23.20	23.00	23.20
Std. Dev		0.71	0.67	0.76	0.72	0.74	0.76	0.76	0.74	0.70	0.70	0.74
No. of Obs.		40	40	40	38	39	40	40	39	37	37	39

Table B-52: Temperature of Raw, Aerated and Column Effluents in 2-day HRT

					Avg. 8.28 cm ³ /cm ² /day HLR				Avg. 10.82 cm ³ /cm ² /day HLR			
Date	Day	Raw Leachate	Aerated Leachate	Distilled Water	Column 1	Column 2	Column 3	Column Avg.	Column 1	Column 2	Column 3	Column Avg.
6-Jul-04	2	20.00	19.50	20.10	20.00	20.15	20.18	20.11	20.17	20.18	20.00	20.12
9-Jul-04	5	21.00	20.00	20.09	20.15	20.00	20.20	20.12	20.12	20.16	20.25	20.18
15-Jul-04	11	20.00	19.50	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
20-Jul-04	16	20.00	19.50	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
25-Jul-04	21	19.50	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00
1-Aug-04	28	21.00	18.00	19.50	19.50	19.50	19.50	19.50	19.50	19.50	19.50	19.50
4-Aug-04	31	20.00	19.00	19.56	19.60	19.50	19.42	19.51	19.57	19.45	19.55	19.52
9-Aug-04	36	19.80	18.50	19.50	19.50	19.50	19.50	19.50	19.50	19.50	19.50	19.50
15-Aug-04	42	21.90	21.00	21.80	21.70	21.82	21.68	21.73	21.60	21.68	21.65	21.64
19-Aug-04	46	23.50	22.00	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50
24-Aug-04	51	22.80	20.50	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
6-Sep-04	64	22.00	21.50	21.87	21.95	21.85	21.89	21.90	21.95	21.89	21.75	21.86
14-Sep-04	72	23.50	22.00	22.80	22.80		22.80	22.80	22.80		22.80	22.80
24-Sep-04	82	22.80	19.50	21.50	21.50		21.50	21.50	21.50		21.50	21.50
27-Sep-04	85	23.00	20.50	21.75			21.68	21.68	21.60			21.60
5-Oct-04	93	22.50	21.50	21.60			21.75	21.75	21.80			21.80
Minimum		19.50	18.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00
Maximum		23.50	22.00	22.80	22.80	21.85	22.80	22.80	22.80	21.89	22.80	22.80
Median		21.45	19.75	20.10	20.00	20.00	20.19	20.11	20.15	20.00	20.00	20.15
Std. Dev		1.45	1.24	1.14	1.14	0.96	1.14	1.14	1.13	0.95	1.12	1.13
No. of Obs.		16	16	16	14	12	16	16	16	12	14	16

Table B-53: Flow rate (ml/day) of Column Effluents in 5-day HRT

Date	Day	Distilled Water	Avg. 8.28 cm ³ /cm ² /day HLR			Avg. 10.82 cm ³ /cm ² /day HLR		
			Column 1	Column 2	Column 3	Column 1	Column 2	Column 3
2-Feb-04	2	850.00	667.00	678.00	666.00	867.00	895.00	886.00
3-Feb-04	3	850.00	640.00	660.00	637.00	870.00	850.00	880.00
4-Feb-04	4	850.00	630.00	655.00	650.00	850.00	825.00	903.00
5-Feb-04	5	855.00	638.00	683.00	636.00	830.00	817.00	890.00
6-Feb-04	6	863.00	638.00	673.00	635.00	889.00	872.00	901.00
9-Feb-04	9	850.00	611.00	658.00	650.00	880.00	848.00	858.50
11-Feb-04	11	869.00	600.00	654.00	630.00	845.00	809.00	876.00
15-Feb-04	15	971.00	614.00	645.00	640.00	840.00	836.00	919.00
16-Feb-04	16	930.00	602.00	630.00	652.00	811.00	814.00	890.00
20-Feb-04	20	927.00	597.00	630.00	600.00	816.00	816.00	910.00
22-Feb-04	22	937.00	591.00	631.00	631.00	784.00	800.00	873.00
24-Feb-04	24	925.00	606.00	615.00	650.00	800.00	805.00	891.00
26-Feb-04	26	890.00	633.00	567.00	615.00	762.00	763.00	826.00
28-Feb-04	28	903.00	596.00	611.00	633.00	793.00	777.00	848.00
1-Mar-04	30	948.00	590.00	622.00	638.00	794.00	797.00	787.00
4-Mar-04	33	943.00	590.00	640.00	635.00	817.00	807.00	732.00
7-Mar-04	36	791.00	589.00	600.00	633.00	779.00	800.00	805.00
10-Mar-04	39	882.00	575.00	600.00	612.00	762.00	795.00	795.00
13-Mar-04	42	850.00	582.00	597.00	513.00	748.00	745.00	720.00
19-Mar-04	48	884.00	569.00	589.00	591.00	786.00	788.00	799.00
22-Mar-04	51	881.00	578.00	570.00	600.00	745.00	745.00	775.00
25-Mar-04	54	880.00	574.00	535.00	608.00	770.00	795.00	774.00
31-Mar-04	60	870.00	558.00	566.00	609.00	757.00	771.00	795.00
3-Apr-04	63	879.00	560.00	570.00	578.00	777.00	768.00	817.00
6-Apr-04	66	887.00	544.00	583.00	563.00	756.00	758.00	825.00
12-Apr-04	72	809.00	576.00	544.00	599.00	779.00	784.00	829.00
21-Apr-04	81	842.00	561.00	520.00	579.00	727.00	745.00	765.00
24-Apr-04	84	850.00	522.00	545.00	548.00	676.00	762.00	755.00
27-Apr-04	87	774.00	530.00	522.00	573.00	722.00	790.00	761.00
30-Apr-04	90	862.00	531.00	566.00	584.00	697.00	755.00	764.00
4-May-04	94	903.00	560.00	575.00	581.00	670.00	761.00	712.00
11-May-04	101	876.00	425.00	511.00	572.00	652.00	242.00*	555.00*
14-May-04	104	857.00	305.00*	500.00	561.00	488.00		
18-May-04	108	850.00		310.00*	550.00	300.00*		
25-May-04	115	856.00			320.00*			

*---Column clogged and the feeding tube was disconnected from the column due to avoid over flooding.

Table B-54: Hydraulic Loading Rate (cm/day) of Column in 5-day HRT

		Distilled Water	Column 1	Column 2	Column 3		Column 1	Column 2	Column 3	
Diameter (cm)		10.73	10.20	10.16	10.20		10.24	10.15	10.16	
Area (cm ²)		90.43	81.71	81.07	81.71		82.36	80.91	81.07	
		Avg. 8.28 cm ³ /cm ² /day HLR					Avg. 10.82 cm ³ /cm ² /day HLR			
Date	Day	Distilled Water	Column 1	Column 2	Column 3	Column Avg.	Column 1	Column 2	Column 3	Column Avg.
2-Feb-04	2	9.40	8.16	8.36	8.15	8.23	10.53	11.06	10.93	10.84
3-Feb-04	3	9.40	7.83	8.14	7.80	7.92	10.56	10.51	10.85	10.64
4-Feb-04	4	9.40	7.71	8.08	7.95	7.91	10.32	10.20	11.14	10.55
5-Feb-04	5	9.45	7.81	8.42	7.78	8.01	10.08	10.10	10.98	10.38
6-Feb-04	6	9.54	7.81	8.30	7.77	7.96	10.79	10.78	11.11	10.90
9-Feb-04	9	9.40	7.48	8.12	7.95	7.85	10.68	10.48	10.59	10.59
11-Feb-04	11	9.61	7.34	8.07	7.71	7.71	10.26	10.00	10.81	10.35
15-Feb-04	15	10.74	7.51	7.96	7.83	7.77	10.20	10.33	11.34	10.62
16-Feb-04	16	10.28	7.37	7.77	7.98	7.71	9.85	10.06	10.98	10.30
20-Feb-04	20	10.25	7.31	7.77	7.34	7.47	9.91	10.09	11.22	10.41
22-Feb-04	22	10.36	7.23	7.78	7.72	7.58	9.52	9.89	10.77	10.06
24-Feb-04	24	10.23	7.42	7.59	7.95	7.65	9.71	9.95	10.99	10.22
26-Feb-04	26	9.84	7.75	6.99	7.53	7.42	9.25	9.43	10.19	9.62
28-Feb-04	28	9.99	7.29	7.54	7.75	7.53	9.63	9.60	10.46	9.90
1-Mar-04	30	10.48	7.22	7.67	7.81	7.57	9.64	9.85	9.71	9.73
4-Mar-04	33	10.43	7.22	7.89	7.77	7.63	9.92	9.97	9.03	9.64
7-Mar-04	36	8.75	7.21	7.40	7.75	7.45	9.46	9.89	9.93	9.76
10-Mar-04	39	9.75	7.04	7.40	7.49	7.31	9.25	9.83	9.81	9.63
13-Mar-04	42	9.40	7.12	7.36	6.28	6.92	9.08	9.21	8.88	9.06
19-Mar-04	48	9.78	6.96	7.27	7.23	7.15	9.54	9.74	9.86	9.71
22-Mar-04	51	9.74	7.07	7.03	7.34	7.15	9.05	9.21	9.56	9.27
25-Mar-04	54	9.73	7.02	6.60	7.44	7.02	9.35	9.83	9.55	9.57
31-Mar-04	60	9.62	6.83	6.98	7.45	7.09	9.19	9.53	9.81	9.51
3-Apr-04	63	9.72	6.85	7.03	7.07	6.99	9.43	9.49	10.08	9.67
6-Apr-04	66	9.81	6.66	7.19	6.89	6.91	9.18	9.37	10.18	9.57
12-Apr-04	72	8.95	7.05	6.71	7.33	7.03	9.46	9.69	10.23	9.79
21-Apr-04	81	9.31	6.87	6.41	7.09	6.79	8.83	9.21	9.44	9.16
24-Apr-04	84	9.40	6.39	6.72	6.71	6.61	8.21	9.42	9.31	8.98
27-Apr-04	87	8.56	6.49	6.44	7.01	6.65	8.77	9.76	9.39	9.31
30-Apr-04	90	9.53	6.50	6.98	7.15	6.88	8.46	9.33	9.42	9.07
4-May-04	94	9.99	6.85	7.09	7.11	7.02	8.14	9.41	8.78	8.77
11-May-04	101	9.69	5.20	6.30	7.00	6.17	7.92	2.99	6.85	5.92
14-May-04	104	9.48	3.73	6.17	6.87	5.59	5.93			5.93
18-May-04	108	9.40		3.82	6.73	5.28	3.64			3.64
25-May-04	115	9.47			3.92	3.92				
Minimum		8.56	3.73	3.82	3.92	3.92	3.64	2.99	6.85	3.64
Maximum		10.74	8.16	8.42	8.15	8.23	10.79	11.06	11.34	10.90
Median		9.62	7.21	7.38	7.45	7.31	9.46	9.83	10.13	9.69
Std. Dev		0.47	0.80	0.88	0.74	0.85	1.36	1.29	0.95	1.50
No. of Obs.		35.00	33.00	34.00	35.00	35.00	34.00	32.00	32.00	34.00

Table B-55: Flow rate (cm³/cm²/day HLR) of Column Effluents in 2-day HRT

Date	Day	Distilled Water	Avg. 8.28 cm ³ /cm ² /day HLR			Avg. 10.82 cm ³ /cm ² /day HLR		
			Column 1	Column 2	Column 3	Column 1	Column 2	Column 3
6-Jul-04	2	822.00	611.00	528.00	623.00	815.00	780.00	860.00
9-Jul-04	5	812.00	625.00	582.00	607.00	853.00	834.00	819.00
15-Jul-04	11	815.00	621.00	580.00	601.00	840.00	830.00	825.00
20-Jul-04	16	816.00	610.00	578.00	589.00	824.00	818.00	835.00
25-Jul-04	21	814.00	584.00	571.00	587.00	814.00	812.00	845.00
1-Aug-04	28	825.00	568.00	555.00	581.00	815.00	819.00	846.00
4-Aug-04	31	830.00	558.00	545.00	580.00	821.00	809.00	848.00
9-Aug-04	36	798.00	572.00	536.00	594.00	815.00	791.00	844.00
15-Aug-04	42	842.00	576.00	556.00	587.00	812.00	800.00	842.00
19-Aug-04	46	845.00	565.00	550.00	589.00	819.00	780.00	869.00
24-Aug-04	51	848.00	558.00	542.00	568.00	821.00	812.00	856.00
29-Aug-04	56	852.00	542.00	551.00	595.00	829.00	768.00	872.00
6-Sep-04	64	867.00	535.00	393.00	591.00	824.00	340.00	874.00
14-Sep-04	72	850.00	515.00		585.00	820.00		850.00
19-Sep-04	77	848.00	518.00		582.00	815.00		835.00
24-Sep-04	82	830.00	361.00		580.00	803.00		760.00
27-Sep-04	85	839.00			538.00	770.00		
5-Oct-04	93	832.00			372.00	558.00		
*---Column clogged and the feeding tube was disconnected from the column due to avoid over flooding.								

Table B-56: Hydraulic Loading Rate (cm/day) of Column in 2-day HRT

		Distilled Water	Column 1	Column 2	Column 3		Column 1	Column 2	Column 3	
Diameter (cm)		10.73	10.20	10.16	10.20		10.24	10.15	10.16	
Area (cm ²)		90.43	81.71	81.07	81.71		82.36	80.91	81.07	
			Avg. 8.28 cm ³ /cm ² /day HLR				Avg. 10.82 cm ³ /cm ² /day HLR			
Date	Day	Distilled Water	Column 1	Column 2	Column 3	Column Avg.	Column 1	Column 2	Column 3	Column Avg.
6-Jul-04	2	9.09	7.48	6.51	7.62	7.21	9.90	9.64	10.61	10.05
9-Jul-04	5	8.98	7.65	7.18	7.43	7.42	10.36	10.31	10.10	10.26
15-Jul-04	11	9.01	7.60	7.15	7.36	7.37	10.20	10.26	10.18	10.21
20-Jul-04	16	9.02	7.47	7.13	7.21	7.27	10.00	10.11	10.30	10.14
25-Jul-04	21	9.00	7.15	7.04	7.18	7.12	9.88	10.04	10.42	10.11
1-Aug-04	28	9.12	6.95	6.85	7.11	6.97	9.90	10.12	10.44	10.15
4-Aug-04	31	9.18	6.83	6.72	7.10	6.88	9.97	10.00	10.46	10.14
9-Aug-04	36	8.82	7.00	6.61	7.27	6.96	9.90	9.78	10.41	10.03
15-Aug-04	42	9.31	7.05	6.86	7.18	7.03	9.86	9.89	10.39	10.04
19-Aug-04	46	9.34	6.91	6.78	7.21	6.97	9.94	9.64	10.72	10.10
24-Aug-04	51	9.38	6.83	6.69	6.95	6.82	9.97	10.04	10.56	10.19
29-Aug-04	56	9.42	6.63	6.80	7.28	6.90	10.07	9.49	10.76	10.10
6-Sep-04	64	9.59	6.55	4.85	7.23	6.21	10.00	4.20	10.78	8.33
14-Sep-04	72	9.40	6.30		7.16	6.73	9.96		10.48	10.22
19-Sep-04	77	9.38	6.34		7.12	6.73	9.90		10.30	10.10
24-Sep-04	82	9.18	4.42		7.10	5.76	9.75		9.37	9.56
27-Sep-04	85	9.28			6.58	6.58	9.35			9.35
5-Oct-04	93	9.20			4.55	4.55	6.78			6.78
Minimum		8.82	4.42	4.85	4.55	4.55	6.78	4.20	9.37	6.78
Maximum		9.59	7.65	7.18	7.62	7.42	10.36	10.31	10.78	10.26
Median		9.19	6.93	6.80	7.18	6.93	9.95	10.00	10.43	10.11
Std. Dev		0.20	0.76	0.60	0.65	0.68	0.77	1.61	0.33	0.88
No. of Obs.		18.00	16.00	13.00	18.00	18.00	18.00	13.00	16.00	18.00

Table B-57: Summary of Cumulative Contaminants Removal of Peat Columns

Phase	Column ID	Total Operational Life (day)	Cumulative Removal (mg/ g of Peat)		
			COD	BOD	TSS
5-day HRT	Controlled Column(DW)	No Clogging	—	—	—
	Avg. 8.28 cm ³ /cm ² /day	Column 1	104	34.68	6.42
		Column 2	108	46.88	9.42
		Column 3	115	48.12	8.86
	Avg. 10.82 cm ³ /cm ² /day	Column 1	108	41.31	7.54
		Column 2	101	48.74	10.42
		Column 3	101	42.06	8.17
2-day HRT	Controlled Column(DW)	No Clogging	—	—	—
	Avg. 8.28 cm ³ /cm ² /day	Column 1	82	30.04	7.65
		Column 2	64	20.90	5.51
		Column 3	93	37.79	9.57
	Avg. 10.82 cm ³ /cm ² /day	Column 1	93	51.68	13.50
		Column 2	64	31.10	5.80
		Column 3	82	46.77	10.60

Table B-58: Cumulative COD (mg/g of Peat) Removal of Column 1 in 5-day HRT

Wt. of Peat (Avg. 8.28 cm³/cm²/day) = (975)*(1-0.5104)=477.36 g of peat
Wt. of Peat (Avg. 10.82 cm³/cm²/day) = (1020)*(1-0.5104)=499.392 g of peat

Day	Day Interval	Aerated Leachate	Flow(mL/d) Avg. 8.28	Flow(mL/d) Avg. 10.82	COD(mg/L) Avg.8.28	COD(mg/L) Avg.10.82	COD Removal Avg.8.28	Cum Removal 8.28	COD Removal Avg.10.82	Cum Removal 10.82
2	2	572.00	667.00	867.00	529.10	406.10	0.06	0.12	0.29	0.58
3	1	497.64	640.00	870.00	258.80	363.20	0.32	0.44	0.23	0.81
4	1	460.46	630.00	850.00	463.30	453.30	0.00	0.44	0.01	0.82
5	1	484.77	638.00	830.00	450.40	440.40	0.05	0.48	0.07	0.90
9	4	697.96	611.00	880.00	598.20	725.80	0.13	0.99	-0.05	0.70
11	2	829.93	600.00	845.00	766.80	766.80	0.08	1.15	0.11	0.91
13	2	857.79	607.00	842.50	699.40	890.00	0.20	1.55	-0.05	0.80
15	2	835.79	614.00	840.00	762.40	1033.00	0.09	1.74	-0.33	0.14
16	1	859.25	602.00	811.00	954.50	989.70	-0.12	1.62	-0.21	-0.07
20	4	975.09	597.00	816.00	966.20	976.50	0.01	1.67	0.00	-0.08
22	2	894.44	591.00	784.00	998.50	892.90	-0.13	1.41	0.00	-0.07
24	2	856.32	606.00	800.00	791.80	862.10	0.08	1.57	-0.01	-0.09
26	2	829.93	633.00	762.00	587.90	677.40	0.32	2.22	0.23	0.37
28	2	778.61	596.00	793.00	456.00	579.10	0.40	3.02	0.32	1.01
30	2	697.96	590.00	794.00	439.80	522.00	0.32	3.66	0.28	1.57
33	3	395.90	590.00	817.00	291.70	338.70	0.13	4.05	0.09	1.85
36	3	306.46	589.00	779.00	208.20	214.00	0.12	4.41	0.14	2.28
39	3	363.64	575.00	762.00	312.30	307.90	0.06	4.60	0.09	2.53
42	3	302.06	582.00	748.00	231.60	359.20	0.09	4.85	-0.09	2.28
45	3	385.64	575.50	767.00	269.80	321.10	0.14	5.27	0.10	2.57
48	3	368.04	569.00	786.00	302.00	334.30	0.08	5.51	0.05	2.73
51	3	326.98	578.00	745.00	133.40	158.30	0.23	6.21	0.25	3.49
54	3	348.98	574.00	770.00	139.30	212.60	0.25	6.97	0.21	4.12
57	3	338.72	566.00	763.50	190.60	126.10	0.18	7.49	0.33	5.09
60	3	266.87	558.00	757.00	291.70	180.30	-0.03	7.41	0.13	5.49
63	3	246.34	560.00	777.00	111.40	151.00	0.16	7.88	0.15	5.93
64	1	137.83	552.00	766.50	74.78	158.30	0.07	7.95	-0.03	5.90
66	2	187.69	544.00	756.00	109.70	140.70	0.09	8.13	0.07	6.04
69	3	183.29	560.00	767.50	85.05	102.60	0.12	8.48	0.12	6.42
72	3	247.80	576.00	779.00	101.10	219.90	0.18	9.01	0.04	6.55
76	4	256.60	569.33	755.89	86.51	143.70	0.20	9.82	0.17	7.23
81	5	856.32	561.00	727.00	79.18	107.00	0.91	14.39	1.09	12.68
84	3	1159.28	522.00	676.00	232.20	318.20	1.01	17.43	1.14	16.10
87	3	746.48	530.00	722.00	347.40	285.50	0.44	18.76	0.67	18.10
90	3	1100.80	531.00	697.00	209.80	309.60	0.99	21.73	1.10	21.41
94	4	1188.52	560.00	670.00	247.60	230.40	1.10	26.15	1.29	26.55
98	4	1092.20	482.86	659.71	182.30	213.20	0.92	29.83	1.16	31.20
101	3	1241.84	425.00	652.00	149.60	108.30	0.97	32.75	1.48	35.64
104	3	1142.08	305.00	488.00	132.40	122.10	0.65	34.68	1.00	38.63
108	4	1212.60		300.00		98.04	0.00	34.68	0.67	41.31
115	7	1147.24					0.00	34.68	0.00	41.31

Table B-59: Cumulative COD (mg/g of Peat) Removal of Column 2 in 5-day HRT

Wt. of Peat (Avg. 8.28 cm³/cm²/day) = (810)*(1-0.5104)=396.576 g of peat
 Wt. of Peat (Avg. 10.82 cm³/cm²/day) = (775)*(1-0.5104)=379.44 g of peat

Day	Day Interval	Aerated Leachate	Flow(mL/d) Avg. 8.28	Flow(mL/d) Avg. 10.82	COD(mg/L) Avg.8.28	COD(mg/L) Avg.10.82	COD Removal Avg.8.28	Cum Removal 8.28	COD Removal Avg.10.82	Cum Removal 10.82
2	2	572.00	678.00	895.00	261.60	303.10	0.53	1.06	0.63	1.27
3	1	497.64	660.00	850.00	253.10	376.00	0.41	1.47	0.27	1.54
4	1	460.46	655.00	825.00	398.90	437.50	0.10	1.57	0.05	1.59
5	1	484.77	683.00	817.00	436.10	429.00	0.08	1.65	0.12	1.71
9	4	697.96	658.00	848.00	589.40	680.30	0.18	2.37	0.04	1.87
11	2	829.93	654.00	809.00	665.70	727.20	0.27	2.92	0.22	2.31
13	2	857.79	649.50	822.50	793.20	843.10	0.11	3.13	0.03	2.37
15	2	835.79	645.00	836.00	909.10	997.00	-0.12	2.89	-0.36	1.66
16	1	859.25	630.00	814.00	923.70	956.00	-0.10	2.79	-0.21	1.45
20	4	975.09	630.00	816.00	975.00	963.30	0.00	2.79	0.03	1.55
22	2	894.44	631.00	800.00	997.00	895.90	-0.16	2.46	0.00	1.55
24	2	856.32	615.00	805.00	828.40	832.80	0.04	2.55	0.05	1.65
26	2	829.93	567.00	763.00	788.80	771.20	0.06	2.67	0.12	1.88
28	2	778.61	611.00	777.00	674.50	659.80	0.16	2.99	0.24	2.37
30	2	697.96	622.00	797.00	501.40	505.80	0.31	3.60	0.40	3.18
33	3	395.90	640.00	807.00	315.20	290.30	0.13	3.99	0.22	3.85
36	3	306.46	600.00	800.00	219.90	183.20	0.13	4.39	0.26	4.63
39	3	363.64	600.00	795.00	294.70	297.60	0.10	4.70	0.14	5.05
42	3	302.06	597.00	745.00	299.10	334.30	0.00	4.71	-0.06	4.86
45	3	385.64	593.00	766.50	272.70	309.30	0.17	5.22	0.15	5.32
48	3	368.04	589.00	788.00	299.10	318.10	0.10	5.53	0.10	5.63
51	3	326.98	570.00	745.00	120.20	126.10	0.30	6.42	0.39	6.81
54	3	348.98	535.00	795.00	136.30	126.10	0.29	7.28	0.47	8.21
57	3	338.72	550.50	783.00	209.60	189.10	0.18	7.82	0.31	9.14
60	3	266.87	566.00	771.00	335.70	234.60	-0.10	7.52	0.07	9.34
63	3	246.34	570.00	768.00	203.80	130.50	0.06	7.70	0.23	10.04
64	1	137.83	576.50	763.00	108.50	70.38	0.04	7.75	0.14	10.18
66	2	187.69	583.00	758.00	118.70	115.80	0.10	7.95	0.14	10.46
69	3	183.29	563.50	771.00	85.05	96.78	0.14	8.37	0.18	10.99
72	3	247.80	544.00	784.00	74.78	52.79	0.24	9.08	0.40	12.20
76	4	256.60	533.33	766.67	86.51	73.32	0.23	10.00	0.37	13.68
81	5	856.32	520.00	745.00	96.78	82.11	1.00	14.98	1.52	21.28
84	3	1159.28	545.00	762.00	240.80	283.80	1.26	18.76	1.76	26.56
87	3	746.48	522.00	790.00	223.60	330.20	0.69	20.83	0.87	29.16
90	3	1100.80	566.00	755.00	283.80	209.80	1.17	24.33	1.77	34.47
94	4	1188.52	575.00	761.00	261.40	237.30	1.34	29.70	1.91	42.11
98	4	1092.20	538.43	464.43	139.30	187.40	1.29	34.88	1.11	46.54
101	3	1241.84	511.00	242.00	98.04	89.44	1.47	39.30	0.73	48.74
104	3	1142.08	500.00		82.56		1.34	43.31	0.00	48.74
108	4	1212.60	310.00		70.52		0.89	46.88	0.00	48.74
115	7	1147.24					0.00	46.88	0.00	48.74

Table B-60: Cumulative COD (mg/g of Peat) Removal of Column 3 in 5-day HRT

Wt. of Peat (Avg. 8.28 cm³/cm²/day) = (975)*(1-0.5104)=477.36 g of peat
Wt. of Peat (Avg. 10.82 cm³/cm²/day) = (970)*(1-0.5104)=474.912 g of peat

Day	Day Interval	Aerated Leachate	Flow(mL/d) Avg. 8.28	Flow(mL/d) Avg. 10.82	COD(mg/L) Avg.8.28	COD(mg/L) Avg.10.82	COD Removal Avg.8.28	Cum Removal 8.28	COD Removal Avg.10.82	Cum Removal 10.82
2	2	572.00	666.00	886.00	247.30	250.20	0.45	0.91	0.60	1.20
3	1	497.64	637.00	880.00	308.80	400.40	0.25	1.16	0.18	1.38
4	1	460.46	650.00	903.00	411.80	414.70	0.07	1.22	0.09	1.47
5	1	484.77	636.00	890.00	439.00	450.40	0.06	1.29	0.06	1.53
9	4	697.96	650.00	858.50	649.50	630.50	0.07	1.55	0.12	2.02
11	2	829.93	630.00	876.00	711.10	806.40	0.16	1.86	0.04	2.11
13	2	857.79	635.00	897.50	812.30	739.00	0.06	1.98	0.22	2.56
15	2	835.79	640.00	919.00	652.50	945.70	0.25	2.48	-0.21	2.13
16	1	859.25	652.00	890.00	938.40	1014.00	-0.11	2.37	-0.29	1.84
20	4	975.09	600.00	910.00	994.10	913.50	-0.02	2.27	0.12	2.31
22	2	894.44	631.00	873.00	973.60	863.60	-0.10	2.06	0.06	2.43
24	2	856.32	650.00	891.00	872.40	819.60	-0.02	2.02	0.07	2.56
26	2	829.93	615.00	826.00	721.40	775.60	0.14	2.30	0.09	2.75
28	2	778.61	633.00	848.00	476.50	728.70	0.40	3.10	0.09	2.93
30	2	697.96	638.00	787.00	429.60	589.40	0.36	3.82	0.18	3.29
33	3	395.90	635.00	732.00	275.60	334.30	0.16	4.30	0.09	3.58
36	3	306.46	633.00	805.00	224.30	234.60	0.11	4.62	0.12	3.94
39	3	363.64	612.00	795.00	284.40	280.00	0.10	4.93	0.14	4.36
42	3	302.06	513.00	720.00	309.30	313.70	-0.01	4.91	-0.02	4.31
45	3	385.64	552.00	759.50	261.00	315.20	0.14	5.34	0.11	4.65
48	3	368.04	591.00	799.00	290.30	297.60	0.10	5.63	0.12	5.00
51	3	326.98	600.00	775.00	123.10	164.20	0.26	6.40	0.27	5.80
54	3	348.98	608.00	774.00	206.70	178.80	0.18	6.94	0.28	6.63
57	3	338.72	608.50	784.50	202.30	265.40	0.17	7.46	0.12	6.99
60	3	266.87	609.00	795.00	309.30	136.30	-0.05	7.30	0.22	7.65
63	3	246.34	578.00	817.00	165.60	174.40	0.10	7.59	0.12	8.02
64	1	137.83	570.50	821.00	193.50	145.10	-0.07	7.52	-0.01	8.01
66	2	187.69	563.00	825.00	114.30	105.50	0.09	7.70	0.14	8.29
69	3	183.29	581.00	827.00	76.25	109.90	0.13	8.09	0.13	8.68
72	3	247.80	599.00	829.00	93.84	82.11	0.19	8.67	0.29	9.54
76	4	256.60	590.11	800.56	70.38	92.38	0.23	9.59	0.28	10.65
81	5	856.32	579.00	765.00	70.38	83.58	0.95	14.36	1.24	16.88
84	3	1159.28	548.00	755.00	354.30	273.40	0.92	17.13	1.41	21.10
87	3	746.48	573.00	761.00	352.60	230.40	0.47	18.55	0.83	23.58
90	3	1100.80	584.00	764.00	225.30	202.90	1.07	21.76	1.44	27.92
94	4	1188.52	581.00	712.00	295.80	233.90	1.09	26.11	1.43	33.64
98	4	1092.20	575.86	622.29	230.40	211.50	1.04	30.26	1.15	38.26
101	3	1241.84	572.00	555.00	94.60	158.20	1.37	34.39	1.27	42.06
104	3	1142.08	561.00		135.80		1.18	37.94	0.00	42.06
108	4	1212.60	550.00		89.44		1.29	43.11	0.00	42.06
115	7	1147.24	320.00		79.12		0.72	48.12	0.00	42.06

Table B-61: Cumulative COD (mg/g of Peat) Removal of Column 1 in 2-day HRT

Wt. of Peat (Avg. 8.28 cm ³ /cm ² /day) = 850*(1-0.1421)=729.215 g of peat										
Wt. of Peat (Avg. 10.82 cm ³ /cm ² /day) = 850*(1-0.1421)=729.215 g of peat										
Day	Day Interval	Aerated Leachate	Flow(mL/d) Avg. 8.28	Flow(mL/d) Avg. 10.82	COD(mg/L) Avg.8.28	COD(mg/L) Avg.10.82	COD Removal Avg.8.28	Cum Removal 8.28	COD Removal Avg.10.82	Cum Removal 10.82
2	2	823.88	611.00	815.00	220.16	120.40	0.51	1.01	0.79	1.57
5	3	918.48	625.00	853.00	589.96	624.36	0.28	1.86	0.34	2.60
8	3	1026.84	623.00	846.50	552.12	686.28	0.41	3.07	0.40	3.79
11	3	1071.56	621.00	840.00	569.32	767.12	0.43	4.36	0.35	4.84
16	5	1228.08	610.00	824.00	1028.50	939.12	0.17	5.19	0.33	6.48
21	5	1155.84	584.00	814.00	946.00	1064.60	0.17	6.03	0.10	6.98
26	5	1157.56	568.00	815.00	584.80	861.72	0.45	8.26	0.33	8.64
31	5	1152.40	558.00	821.00	555.56	670.80	0.46	10.55	0.54	11.35
36	5	951.16	572.00	815.00	282.08	242.52	0.52	13.17	0.79	15.31
42	6	1002.76	576.00	812.00	151.36	98.04	0.67	17.20	1.01	21.35
47	5	540.08	565.00	819.00	127.28	106.64	0.32	18.80	0.49	23.79
51	4	385.28	558.00	821.00	12.04	61.92	0.29	19.95	0.36	25.24
57	6	540.08	542.00	829.00	199.52	87.72	0.25	21.47	0.51	28.33
64	7	903.00	535.00	824.00	165.12	110.08	0.54	25.25	0.90	34.60
72	8	799.80	515.00	820.00	357.76	197.80	0.31	27.75	0.68	40.02
82	10	808.40	361.00	803.00	345.72	223.60	0.23	30.04	0.64	46.46
85	3	772.28		770.00		209.84	0.00	30.04	0.59	48.24
93	8	772.28		558.00		209.84	0.00	30.04	0.43	51.68

Table B-62: Cumulative COD (mg/g of Peat) Removal of Column 2 in 2-day HRT

Wt. of Peat (Avg. 8.28 cm³/cm²/day) = 850*(1-0.1421)=729.215 g of peat
 Wt. of Peat (Avg. 10.82 cm³/cm²/day) = 850*(1-0.1421)=729.215 g of peat

Day	Day Interval	Aerated Leachate	Flow(mL/d) Avg. 8.28	Flow(mL/d) Avg. 10.82	COD(mg/L) Avg.8.28	COD(mg/L) Avg.10.82	COD Removal Avg.8.28	Cum Removal 8.28	COD Removal Avg.10.82	Cum Removal 10.82
2	2	823.88	528.00	780.00	252.84	201.24	0.41	0.83	0.67	1.33
5	3	918.48	582.00	834.00	445.48	552.12	0.38	1.96	0.42	2.59
8	3	1026.84	581.00	832.00	488.48	586.52	0.43	3.25	0.50	4.10
11	3	1071.56	580.00	830.00	620.92	660.48	0.36	4.32	0.47	5.50
16	5	1228.08	578.00	818.00	860.00	784.32	0.29	5.78	0.50	7.99
21	5	1155.84	571.00	812.00	1147.20	1193.60	0.01	5.81	-0.04	7.78
26	5	1157.56	555.00	819.00	930.52	798.08	0.17	6.68	0.40	9.80
31	5	1152.40	545.00	809.00	866.88	765.40	0.21	7.75	0.43	11.94
36	5	951.16	536.00	791.00	309.60	252.84	0.47	10.10	0.76	15.73
42	6	1002.76	556.00	800.00	159.96	29.24	0.64	13.96	1.07	22.14
47	5	540.08	550.00	780.00	142.76	46.44	0.30	15.46	0.53	24.78
51	4	385.28	542.00	812.00	118.68	36.12	0.20	16.25	0.39	26.33
57	6	540.08	551.00	768.00	130.72	146.20	0.31	18.11	0.41	28.82
64	7	903.00	393.00	340.00	161.67	206.40	0.40	20.90	0.32	31.10
72	8	799.80					0.00	20.90	0.00	31.10
82	10	808.40					0.00	20.90	0.00	31.10
85	3	772.28					0.00	20.90	0.00	31.10
93	8	772.28					0.00	20.90	0.00	31.10

Table B-63: Cumulative COD (mg/g of Peat) Removal of Column 3 in 2-day HRT

Wt. of Peat (Avg. 8.28 cm ³ /cm ² /day) = 850*(1-0.1421)=729.215 g of peat										
Wt. of Peat (Avg. 10.82 cm ³ /cm ² /day) = 850*(1-0.1421)=729.215 g of peat										
Day	Day Interval	Aerated Leachate	Flow(mL/d) Avg. 8.28	Flow(mL/d) Avg. 10.82	COD(mg/L) Avg.8.28	COD(mg/L) Avg.10.82	COD Removal Avg.8.28	Cum Removal 8.28	COD Removal Avg.10.82	Cum Removal 10.82
2	2	823.88	623.00	860.00	103.20	178.88	0.62	1.23	0.76	1.52
5	3	918.48	607.00	819.00	347.44	615.76	0.48	2.66	0.34	2.54
8	3	1026.84	604.00	822.00	524.60	655.32	0.42	3.91	0.42	3.80
11	3	1071.56	601.00	825.00	694.88	670.80	0.31	4.84	0.45	5.16
16	5	1228.08	589.00	835.00	940.84	994.16	0.23	6.00	0.27	6.50
21	5	1155.84	587.00	845.00	937.40	1049.20	0.18	6.88	0.12	7.12
26	5	1157.56	581.00	846.00	710.36	868.60	0.36	8.66	0.34	8.79
31	5	1152.40	580.00	848.00	655.32	665.64	0.40	10.63	0.57	11.62
36	5	951.16	594.00	844.00	166.84	258.00	0.64	13.83	0.80	15.63
42	6	1002.76	587.00	842.00	104.92	103.20	0.72	18.17	1.04	21.86
47	5	540.08	589.00	869.00	96.32	137.60	0.36	19.96	0.48	24.26
51	4	385.28	568.00	856.00	8.60	159.96	0.29	21.13	0.26	25.32
57	6	540.08	595.00	872.00	46.44	127.28	0.40	23.55	0.49	28.28
64	7	903.00	591.00	874.00	87.72	104.92	0.66	28.17	0.96	34.98
72	8	799.80	585.00	850.00	357.76	206.40	0.35	31.01	0.69	40.51
82	10	808.40	580.00	760.00	321.64	208.12	0.39	34.88	0.63	46.77
85	3	772.28	538.00		309.60		0.34	35.91	0.00	46.77
93	8	772.28	372.00		309.60		0.24	37.79	0.00	46.77

Table B-64: Cumulative BOD (mg/g of Peat) Removal of Column 1 in 5-day HRT

Day	Day Interval	Aerated Leachate	Flow(mL/d) Avg. 8.28	Flow(mL/d) Avg. 10.82	BOD(mg/L) Avg.8.28	BOD(mg/L) Avg.10.82	BOD Removal Avg.8.28	Cum Removal 8.28	BOD Removal Avg.10.82	Cum Removal 10.82
13	13	25.27	607.00	842.50	47.30	77.90	-0.03	-0.36	-0.09	-1.15
18	5	32.03	599.00	813.50	33.92	35.72	0.00	-0.38	-0.01	-1.18
21	3	20.20	594.00	800.00	16.70	25.55	0.00	-0.36	-0.01	-1.21
25	4	13.42	619.50	781.00	16.16	51.71	0.00	-0.38	-0.06	-1.45
28	3	76.88	596.00	793.00	53.89	74.44	0.03	-0.29	0.00	-1.44
37	9	16.20	589.00	779.00	12.75	17.55	0.00	-0.25	0.00	-1.46
40	3	37.50	577.33	757.33	30.30	25.20	0.01	-0.23	0.02	-1.40
50	10	46.30	578.00	745.00	22.40	24.65	0.03	0.06	0.03	-1.08
70	20	40.00	560.00	767.50	15.05	15.20	0.03	0.65	0.04	-0.32
75	5	72.50	569.33	755.89	7.45	20.65	0.08	1.04	0.08	0.08
84	9	220.90	522.00	676.00	17.60	10.55	0.22	3.04	0.28	2.64
88	4	141.10	530.00	722.00	4.70	10.25	0.15	3.64	0.19	3.40
94	6	165.10	560.00	670.00	15.05	14.75	0.18	4.70	0.20	4.61
98	4	238.90	482.86	659.71	30.95	14.30	0.21	5.54	0.30	5.79
101	3	203.10	425.00	652.00	11.70	14.70	0.17	6.05	0.25	6.53
104	3	203.10	305.00	488.00	11.70	14.70	0.12	6.42	0.18	7.08
108	4	203.10		300.00		14.70	0.00	6.42	0.11	7.54
110	2	221.70					0.00	6.42	0.00	7.54
115	5	221.70					0.00	6.42	0.00	7.54

Table B-65: Cumulative BOD (mg/g of Peat) Removal of Column 2 in 5-day HRT

Day	Day Interval	Aerated Leachate	Flow(mL/d) Avg. 8.28	Flow(mL/d) Avg. 10.82	BOD(mg/L) Avg.8.28	BOD(mg/L) Avg.10.82	BOD Removal Avg.8.28	Cum Removal 8.28	BOD Removal Avg.10.82	Cum Removal 10.82
13	13	25.27	649.50	822.50	16.85	19.70	0.01	0.18	0.01	0.16
18	5	32.03	630.00	815.00	40.07	29.87	-0.01	0.12	0.00	0.18
21	3	20.20	630.50	808.00	15.05	18.50	0.01	0.14	0.00	0.19
25	4	13.42	591.00	784.00	27.56	15.26	-0.02	0.06	0.00	0.18
28	3	76.88	611.00	777.00	43.54	63.19	0.05	0.21	0.03	0.26
37	9	16.20	600.00	800.00	15.75	30.60	0.00	0.22	-0.03	-0.01
40	3	37.50	599.00	778.33	23.70	29.25	0.02	0.28	0.02	0.04
50	10	46.30	570.00	745.00	26.75	21.80	0.03	0.56	0.05	0.52
70	20	40.00	563.50	771.00	20.15	12.50	0.03	1.12	0.06	1.64
75	5	72.50	533.33	766.67	9.85	16.75	0.08	1.54	0.11	2.20
84	9	220.90	545.00	762.00	8.45	8.30	0.29	4.17	0.43	6.04
88	4	141.10	522.00	790.00	14.45	9.35	0.17	4.84	0.27	7.14
94	6	165.10	575.00	761.00	14.00	13.85	0.22	6.15	0.30	8.96
98	4	238.90	538.43	464.43	10.55	14.90	0.31	7.39	0.27	10.06
101	3	203.10	511.00	242.00	14.70	11.10	0.24	8.12	0.12	10.42
104	3	203.10	500.00		14.70		0.24	8.83	0.00	10.42
108	4	203.10	310.00		14.70		0.15	9.42	0.00	10.42
110	2	221.70					0.00	9.42	0.00	10.42
115	5	221.70					0.00	9.42	0.00	10.42

Table B-66: Cumulative BOD (mg/g of Peat) Removal of Column 3 in 5-day HRT

Day	Day Interval	Aerated Leachate	Flow(mL/d) Avg. 8.28	Flow(mL/d) Avg. 10.82	BOD(mg/L) Avg.8.28	BOD(mg/L) Avg.10.82	BOD Removal Avg.8.28	Cum Removal 8.28	BOD Removal Avg.10.82	Cum Removal 10.82
13	13	25.27	635.00	897.50	42.05	28.55	-0.02	-0.29	-0.01	-0.08
18	5	32.03	626.00	900.00	33.02	26.42	0.00	-0.30	0.01	-0.03
21	3	20.20	615.50	891.50	11.90	28.55	0.01	-0.26	-0.02	-0.07
25	4	13.42	632.50	858.50	35.81	70.61	-0.03	-0.38	-0.10	-0.49
28	3	76.88	633.00	848.00	65.14	49.69	0.02	-0.34	0.05	-0.34
37	9	16.20	633.00	805.00	18.60	33.30	0.00	-0.37	-0.03	-0.60
40	3	37.50	579.00	770.00	24.45	25.65	0.02	-0.32	0.02	-0.55
50	10	46.30	600.00	775.00	32.45	22.40	0.02	-0.14	0.04	-0.16
70	20	40.00	581.00	827.00	24.05	14.45	0.02	0.24	0.04	0.73
75	5	72.50	590.11	800.56	24.10	17.20	0.06	0.54	0.09	1.20
84	9	220.90	548.00	755.00	7.10	12.80	0.25	2.75	0.33	4.18
88	4	141.10	573.00	761.00	7.85	4.70	0.16	3.39	0.22	5.05
94	6	165.10	581.00	712.00	15.80	14.60	0.18	4.48	0.23	6.41
98	4	238.90	575.86	622.29	15.80	33.95	0.27	5.56	0.27	7.48
101	3	203.10	572.00	555.00	13.65	6.75	0.23	6.24	0.23	8.17
104	3	203.10	561.00		13.65		0.22	6.91	0.00	8.17
108	4	203.10	550.00		13.65		0.22	7.78	0.00	8.17
110	2	221.70	435.00		13.65		0.19	8.16	0.00	8.17
115	5	221.70	320.00		13.65		0.14	8.86	0.00	8.17

Table B-67: Cumulative BOD (mg/g of Peat) Removal of Column 1 in 2-day HRT

Day	Day Interval	Aerated Leachate	Flow(mL/d) Avg. 8.28	Flow(mL/d) Avg. 10.82	BOD(mg/L) Avg.8.28	BOD(mg/L) Avg.10.82	BOD Removal Avg.8.28	Cum Removal 8.28	BOD Removal Avg.10.82	Cum Removal 10.82
6	6	43.30	625.00	853.00	31.25	30.05	0.01	0.06	0.02	0.09
11	5	47.10	621.00	840.00	17.70	9.60	0.03	0.19	0.04	0.31
16	5	109.90	610.00	824.00	29.15	38.45	0.07	0.52	0.08	0.71
21	5	233.30	584.00	814.00	47.05	53.35	0.15	1.27	0.20	1.72
31	10	238.00	558.00	821.00	12.20	15.80	0.17	3.00	0.25	4.22
36	5	237.40	572.00	815.00	17.45	9.95	0.17	3.86	0.25	5.49
42	6	39.30	576.00	812.00	4.50	3.00	0.03	4.03	0.04	5.73
51	9	92.90	558.00	821.00	2.20	11.35	0.07	4.65	0.09	6.56
64	13	132.20	535.00	824.00	8.30	10.65	0.09	5.83	0.14	8.34
72	8	132.20	515.00	820.00	8.30	10.65	0.09	6.53	0.14	9.44
77	5	212.23	438.00	811.50	8.70	12.89	0.12	7.14	0.22	10.55
82	5	212.23	361.00	803.00	8.70	12.89	0.10	7.65	0.22	11.64
85	3	212.23		770.00		12.89	0.00	7.65	0.21	12.28
93	8	212.23		558.00		12.89	0.00	7.65	0.15	13.50

Table B-68: Cumulative BOD (mg/g of Peat) Removal of Column 2 in 2-day HRT

Day	Day Interval	Aerated Leachate	Flow(mL/d) Avg. 8.28	Flow(mL/d) Avg. 10.82	BOD(mg/L) Avg.8.28	BOD(mg/L) Avg.10.82	BOD Removal Avg.8.28	Cum Removal 8.28	BOD Removal Avg.10.82	Cum Removal 10.82
6	6	43.30	582.00	834.00	34.10	37.85	0.01	0.04	0.01	0.04
11	5	47.10	580.00	830.00	14.70	10.35	0.03	0.17	0.04	0.25
16	5	109.90	578.00	818.00	3.50	16.10	0.08	0.59	0.11	0.77
21	5	233.30	571.00	812.00	42.10	118.60	0.15	1.34	0.13	1.41
31	10	238.00	545.00	809.00	7.70	119.70	0.17	3.06	0.13	2.72
36	5	237.40	536.00	791.00	8.45	12.65	0.17	3.91	0.24	3.94
42	6	39.30	556.00	800.00	3.90	1.95	0.03	4.07	0.04	4.19
51	9	92.90	542.00	812.00	3.55	5.95	0.07	4.67	0.10	5.06
64	13	132.20	393.00	340.00	12.31	9.62	0.06	5.51	0.06	5.80
72	8	132.20					0.00	5.51	0.00	5.80
77	5	212.23					0.00	5.51	0.00	5.80
82	5	212.23					0.00	5.51	0.00	5.80
85	3	212.23					0.00	5.51	0.00	5.80
93	8	212.23					0.00	5.51	0.00	5.80

Table B-69: Cumulative BOD (mg/g of Peat) Removal of Column 3 in 2-day HRT

Day	Day Interval	Aerated Leachate	Flow(mL/d) Avg. 8.28	Flow(mL/d) Avg. 10.82	BOD(mg/L) Avg.8.28	BOD(mg/L) Avg.10.82	BOD Removal Avg.8.28	Cum Removal 8.28	BOD Removal Avg.10.82	Cum Removal 10.82
6	6	43.30	607.00	819.00	36.50	19.70	0.01	0.03	0.03	0.16
11	5	47.10	601.00	825.00	23.55	10.20	0.02	0.13	0.04	0.37
16	5	109.90	589.00	835.00	33.20	21.35	0.06	0.44	0.10	0.87
21	5	233.30	587.00	845.00	69.40	121.60	0.13	1.10	0.13	1.52
31	10	238.00	580.00	848.00	8.75	104.40	0.18	2.92	0.16	3.08
36	5	237.40	594.00	844.00	12.65	11.90	0.18	3.84	0.26	4.38
42	6	39.30	587.00	842.00	13.50	3.45	0.02	3.96	0.04	4.63
51	9	92.90	568.00	856.00	3.85	13.45	0.07	4.59	0.09	5.47
64	13	132.20	591.00	874.00	9.16	10.45	0.10	5.88	0.15	7.37
72	8	132.20	585.00	850.00	9.16	10.45	0.10	6.67	0.14	8.50
77	5	212.23	582.50	805.00	9.51	16.52	0.16	7.48	0.22	9.58
82	5	212.23	580.00	760.00	9.51	16.52	0.16	8.29	0.20	10.60
85	3	212.23	538.00		9.51		0.15	8.74	0.00	10.60
93	8	212.23	372.00		9.51		0.10	9.57	0.00	10.60

Table B-70: Cumulative TSS (mg/g of Peat) Removal of Column 1 in 5-day HRT

Day	Day Interval	Aerated Leachate	Flow(mL/d) Avg. 8.28	Flow(mL/d) Avg. 10.82	TSS(mg/L) Avg.8.28	TSS(mg/L) Avg.10.82	TSS Removal Avg.8.28	Cum Removal 8.28	TSS Removal Avg.10.82	Cum Removal 10.82
5	5	40.400	638.000	830.000	49.600	32.100	-0.012	-0.061	0.014	0.069
9	4	30.000	611.000	880.000	35.000	5.000	-0.006	-0.087	0.044	0.245
11	2	15.500	600.000	845.000	39.000	7.000	-0.030	-0.146	0.014	0.274
13	2	35.000	607.000	842.500	42.500	10.500	-0.010	-0.165	0.041	0.357
15	2	25.630	614.000	840.000	4.000	0.000	0.028	-0.110	0.043	0.443
17	2	5.000	600.750	812.250	3.000	1.000	0.003	-0.105	0.007	0.456
19	2	10.500	593.438	791.063	2.500	2.000	0.010	-0.085	0.013	0.483
21	2	6.000	594.000	800.000	0.500	1.000	0.007	-0.071	0.008	0.499
23	2	7.000	598.500	792.000	8.000	1.000	-0.001	-0.073	0.010	0.518
25	2	9.500	619.500	781.000	2.500	0.500	0.009	-0.055	0.014	0.546
27	2	9.000	614.500	777.500	3.000	1.500	0.008	-0.040	0.012	0.569
29	2	8.500	593.000	793.500	1.500	3.000	0.009	-0.022	0.009	0.587
31	2	10.000	590.000	805.500	0.000	0.000	0.012	0.002	0.016	0.619
33	2	11.000	590.000	817.000	4.500	1.000	0.008	0.018	0.016	0.652
36	3	11.500	589.000	779.000	2.000	0.500	0.012	0.053	0.017	0.703
39	3	4.000	575.000	762.000	14.000	15.000	-0.012	0.017	-0.017	0.653
42	3	8.000	582.000	748.000	6.500	6.000	0.002	0.023	0.003	0.662
45	3	9.500	575.500	767.000	3.000	2.500	0.008	0.046	0.011	0.694
48	3	6.000	569.000	786.000	6.500	6.000	-0.001	0.045	0.000	0.694
51	3	9.500	578.000	745.000	16.500	11.500	-0.008	0.019	-0.003	0.685
54	3	7.500	574.000	770.000	5.000	3.000	0.003	0.028	0.007	0.706
70	16	123.000	565.333	771.333	0.000	13.000	0.146	2.359	0.170	3.424
81	11	170.000	561.000	727.000	0.000	13.000	0.200	4.556	0.229	5.939
84	3	161.000	522.000	676.000	11.300	13.100	0.164	5.048	0.200	6.539
87	3	359.000	530.000	722.000	11.900	14.800	0.385	6.204	0.498	8.032
94	7	295.100	560.000	670.000	18.300	20.100	0.325	8.477	0.369	10.615
101	7	317.100	425.000	652.000	17.500	16.800	0.267	10.344	0.392	13.359
104	3	317.100	305.000	488.000	17.500	16.800	0.191	10.918	0.293	14.240
108	4	317.100		300.000		16.800	0.000	10.918	0.180	14.961
115	7	317.100					0.000	10.918	0.000	14.961

Table B-71: Cumulative TSS (mg/g of Peat) Removal of Column 2 in 5-day HRT

Day	Day Interval	Aerated Leachate	Flow(mL/d) Avg. 8.28	Flow(mL/d) Avg. 10.82	TSS(mg/L) Avg.8.28	TSS(mg/L) Avg.10.82	TSS Removal Avg.8.28	Cum Removal 8.28	TSS Removal Avg.10.82	Cum Removal 10.82
5	5	40.400	683.000	817.000	16.900	18.500	0.040	0.202	0.047	0.236
9	4	30.000	658.000	848.000	9.500	1.000	0.034	0.338	0.065	0.495
11	2	15.500	654.000	809.000	16.500	4.000	-0.002	0.335	0.025	0.544
13	2	35.000	649.500	822.500	15.500	8.500	0.032	0.399	0.057	0.659
15	2	25.630	645.000	836.000	0.000	1.500	0.042	0.482	0.053	0.765
17	2	5.000	630.000	814.500	0.000	0.000	0.008	0.498	0.011	0.787
19	2	10.500	630.750	803.625	1.500	1.000	0.014	0.527	0.020	0.827
21	2	6.000	630.500	808.000	0.000	1.500	0.010	0.546	0.010	0.846
23	2	7.000	623.000	802.500	2.000	2.000	0.008	0.562	0.011	0.867
25	2	9.500	591.000	784.000	4.000	1.000	0.008	0.578	0.018	0.902
27	2	9.000	589.000	770.000	3.500	2.500	0.008	0.594	0.013	0.929
29	2	8.500	616.500	787.000	6.000	2.000	0.004	0.602	0.013	0.956
31	2	10.000	631.000	802.000	0.500	2.000	0.015	0.632	0.017	0.990
33	2	11.000	640.000	807.000	1.000	0.500	0.016	0.665	0.022	1.034
36	3	11.500	600.000	800.000	5.500	1.500	0.009	0.692	0.021	1.097
39	3	4.000	600.000	795.000	7.000	5.000	-0.005	0.678	-0.002	1.091
42	3	8.000	597.000	745.000	2.000	2.000	0.009	0.705	0.012	1.127
45	3	9.500	593.000	766.500	1.000	3.500	0.013	0.744	0.012	1.163
48	3	6.000	589.000	788.000	1.500	2.500	0.007	0.764	0.007	1.185
51	3	9.500	570.000	745.000	1.000	0.500	0.012	0.800	0.018	1.238
54	3	7.500	535.000	795.000	1.000	3.000	0.009	0.827	0.009	1.266
70	16	123.000	557.000	775.333	10.000	9.000	0.159	3.366	0.233	4.993
81	11	170.000	520.000	745.000	10.000	9.000	0.210	5.674	0.316	8.470
84	3	161.000	545.000	762.000	11.700	12.100	0.205	6.289	0.299	9.367
87	3	359.000	522.000	790.000	10.800	11.800	0.458	7.664	0.723	11.536
94	7	295.100	575.000	761.000	17.300	21.100	0.403	10.484	0.550	15.383
101	7	317.100	511.000	242.000	16.000	19.500	0.388	13.199	0.190	16.711
104	3	317.100	500.000		16.000		0.380	14.338	0.000	16.711
108	4	317.100	310.000		16.000		0.235	15.280	0.000	16.711
115	7	317.100					0.000	15.280	0.000	16.711

Table B-72: Cumulative TSS (mg/g of Peat) Removal of Column 3 in 5-day HRT

Day	Day Interval	Aerated Leachate	Flow(mL/d) Avg. 8.28	Flow(mL/d) Avg. 10.82	TSS(mg/L) Avg.8.28	TSS(mg/L) Avg.10.82	TSS Removal Avg.8.28	Cum Removal 8.28	TSS Removal Avg.10.82	Cum Removal 10.82
5	5	40.400	636.000	890.000	40.050	43.000	0.000	0.002	-0.005	-0.024
9	4	30.000	650.000	858.500	14.000	10.000	0.022	0.089	0.036	0.120
11	2	15.500	630.000	876.000	22.000	5.000	-0.009	0.072	0.019	0.159
13	2	35.000	635.000	897.500	17.000	3.500	0.024	0.120	0.060	0.278
15	2	25.630	640.000	919.000	0.000	0.500	0.034	0.189	0.049	0.375
17	2	5.000	639.000	895.000	1.000	0.000	0.005	0.200	0.009	0.394
19	2	10.500	633.000	878.500	1.500	0.500	0.012	0.224	0.018	0.431
21	2	6.000	615.500	891.500	0.500	0.000	0.007	0.238	0.011	0.454
23	2	7.000	640.500	882.000	0.500	0.500	0.009	0.255	0.012	0.478
25	2	9.500	632.500	858.500	2.000	2.000	0.010	0.275	0.014	0.505
27	2	9.000	624.000	837.000	0.500	3.500	0.011	0.297	0.010	0.524
29	2	8.500	635.500	817.500	4.500	3.500	0.005	0.308	0.009	0.542
31	2	10.000	636.500	759.500	0.500	2.000	0.013	0.333	0.013	0.567
33	2	11.000	635.000	732.000	1.500	0.000	0.013	0.358	0.017	0.601
36	3	11.500	633.000	805.000	3.000	2.500	0.011	0.392	0.015	0.647
39	3	4.000	612.000	795.000	9.500	11.500	-0.007	0.371	-0.013	0.609
42	3	8.000	513.000	720.000	10.500	2.500	-0.003	0.363	0.008	0.634
45	3	9.500	552.000	759.500	7.500	1.500	0.002	0.370	0.013	0.673
48	3	6.000	591.000	799.000	16.000	1.500	-0.012	0.333	0.008	0.695
51	3	9.500	600.000	775.000	8.000	2.000	0.002	0.339	0.012	0.732
54	3	7.500	608.000	774.000	10.000	4.000	-0.003	0.329	0.006	0.749
70	16	123.000	587.000	827.667	0.000	14.000	0.151	2.749	0.190	3.788
81	11	170.000	579.000	765.000	0.000	14.000	0.206	5.017	0.251	6.553
84	3	161.000	548.000	755.000	11.600	12.500	0.172	5.532	0.236	7.261
87	3	359.000	573.000	761.000	10.000	7.500	0.419	6.788	0.563	8.951
94	7	295.100	581.000	712.000	14.500	15.200	0.342	9.179	0.420	11.888
101	7	317.100	572.000	555.000	14.700	13.400	0.362	11.716	0.355	14.372
104	3	317.100	561.000		14.700		0.355	12.782	0.000	14.372
108	4	317.100	550.000		14.700		0.348	14.175	0.000	14.372
115	7	317.100	320.000		14.700		0.203	15.594	0.000	14.372

Table B-73: Cumulative TSS (mg/g of Peat) Removal of Column 1 in 2-day HRT

Day	Day Interval	Aerated Leachate	Flow(mL/d) Avg. 8.28	Flow(mL/d) Avg. 10.82	TSS(mg/L) Avg.8.28	TSS(mg/L) Avg.10.82	TSS Removal Avg.8.28	Cum Removal 8.28	TSS Removal Avg.10.82	Cum Removal 10.82
2	2	28.000	625.000	853.000	14.000	9.000	0.012	0.024	0.022	0.044
16	14	58.000	610.000	824.000	31.000	23.000	0.023	0.340	0.040	0.598
21	5	120.000	584.000	814.000	61.000	81.000	0.047	0.576	0.044	0.816
31	10	31.000	558.000	821.000	21.000	40.000	0.008	0.653	-0.010	0.714
36	5	15.000	572.000	815.000	21.300	14.000	-0.005	0.628	0.001	0.720
42	6	60.000	576.000	812.000	20.000	27.000	0.032	0.818	0.037	0.941
51	9	71.000	558.000	821.000	40.000	51.000	0.024	1.031	0.023	1.143
64	13	107.000	535.000	824.000	21.000	59.000	0.063	1.852	0.054	1.848
72	8	93.000	515.000	820.000	36.000	38.000	0.040	2.174	0.062	2.343
78	6	150.000	438.000	811.500	35.000	60.000	0.069	2.588	0.100	2.944
82	4	194.000	361.000	803.000	34.000	38.000	0.079	2.905	0.172	3.631
85	3	204.000		770.000		35.000	0.000	2.905	0.178	4.167
93	8	204.000		558.000		35.000	0.000	2.905	0.129	5.201

Table B-74: Cumulative TSS (mg/g of Peat) Removal of Column 2 in 2-day HRT

Day	Day Interval	Aerated Leachate	Flow(mL/d) Avg. 8.28	Flow(mL/d) Avg. 10.82	TSS(mg/L) Avg.8.28	TSS(mg/L) Avg.10.82	TSS Removal Avg.8.28	Cum Removal 8.28	TSS Removal Avg.10.82	Cum Removal 10.82
2	2	28.000	582.000	834.000	7.000	38.000	0.017	0.034	-0.011	-0.023
16	14	58.000	578.000	818.000	20.000	22.000	0.030	0.455	0.040	0.542
21	5	120.000	571.000	812.000	50.000	73.000	0.055	0.729	0.052	0.804
31	10	31.000	545.000	809.000	25.000	63.000	0.004	0.774	-0.036	0.449
36	5	15.000	536.000	791.000	56.000	18.000	-0.030	0.623	-0.003	0.433
42	6	60.000	556.000	800.000	41.000	45.000	0.014	0.710	0.016	0.532
51	9	71.000	542.000	812.000	25.000	41.000	0.034	1.018	0.033	0.832
64	13	107.000	393.000	340.000	52.000	27.000	0.030	1.403	0.037	1.317
72	8	93.000					0.000	1.403	0.000	1.317
78	6	150.000					0.000	1.403	0.000	1.317
82	4	194.000					0.000	1.403	0.000	1.317
85	3	204.000					0.000	1.403	0.000	1.317

Table B-75: Cumulative TSS (mg/g of Peat) Removal of Column 3 in 2-day HRT

Day	Day Interval	Aerated Leachate	Flow(mL/d) Avg. 8.28	Flow(mL/d) Avg. 10.82	TSS(mg/L) Avg.8.28	TSS(mg/L) Avg.10.82	TSS Removal Avg.8.28	Cum Removal 8.28	TSS Removal Avg.10.82	Cum Removal 10.82
2	2	28.000	607.000	819.000	13.000	33.000	0.012	0.025	-0.006	-0.011
16	14	58.000	589.000	835.000	30.000	45.000	0.023	0.342	0.015	0.197
21	5	120.000	587.000	845.000	71.000	74.000	0.039	0.539	0.053	0.464
31	10	31.000	580.000	848.000	33.000	60.000	-0.002	0.523	-0.034	0.126
36	5	15.000	594.000	844.000	7.000	21.000	0.007	0.555	-0.007	0.092
42	6	60.000	587.000	842.000	22.000	15.000	0.031	0.739	0.052	0.403
51	9	71.000	568.000	856.000	27.000	38.000	0.034	1.047	0.039	0.752
64	13	107.000	591.000	874.000	29.000	47.000	0.063	1.869	0.072	1.687
72	8	93.000	585.000	850.000	36.000	50.000	0.046	2.235	0.050	2.088
78	6	150.000	582.500	805.000	41.000	75.000	0.087	2.758	0.083	2.585
82	4	194.000	580.000	760.000	53.000	31.000	0.112	3.206	0.170	3.264
85	3	204.000	538.000		41.000		0.120	3.567	0.000	3.264
93	8	204.000	372.000		41.000		0.083	4.232	0.000	3.264

ANOVA Study of Cumulative Contaminants Removal Through Peat Columns:

Cumulative COD Removal (mg/ g of Peat)

5-day HRT

Column ID	Avg. 8.28 cm ³ /cm ² /day	Avg. 10.82 cm ³ /cm ² /day
Column 1	34.68	41.31
Column 2	46.88	48.74
Column 3	48.12	42.06

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Column 1	3	129.68	43.22666667	55.16853
Column 2	3	132.11	44.03666667	16.73163

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.98415	1	0.98415	0.027375	0.876611	7.70865
Within Groups	143.80033	4	35.95008333			
Total	144.78448	5				

Cumulative COD Removal (mg/ g of Peat)

2-day HRT

Column ID	Avg. 8.28 cm ³ /cm ² /day	Avg. 10.82 cm ³ /cm ² /day
Column 1	30.04	51.68
Column 2	20.90	31.10
Column 3	37.79	46.77

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Column 1	3	88.73	29.57666667	71.47903
Column 2	3	129.55	43.18333333	115.5322

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	277.71207	1	277.7120667	2.970004	0.159918	7.70865
Within Groups	374.02253	4	93.50563333			
Total	651.7346	5				

Cumulative COD Removal (mg/ g of Peat)
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5-day and 2-day HRT

	Column ID	5-day HRT	2-day HRT
Avg. 8.28 cm ³ /cm ² /day	Column 1	34.68	30.04
	Column 2	46.88	20.90
	Column 3	48.12	37.79
Avg. 10.82 cm ³ /cm ² /day	Column 1	41.31	51.68
	Column 2	48.74	31.10
	Column 3	42.06	46.77

Anova: Single Factor

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
Column 1	6	261.79	43.63166667	28.9569
Column 2	6	218.28	36.38	130.3469

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	157.76001	1	157.7600083	1.980618	0.18964	4.964591
Within Groups	796.51908	10	79.65190833			
Total	954.27909	11				

Cumulative BOD Removal (mg/ g of Peat)

5-day HRT

Column ID	Avg. 8.28 cm ³ /cm ² /day	Avg. 10.82 cm ³ /cm ² /day
Column 1	6.42	7.54
Column 2	9.42	10.42
Column 3	8.86	8.17

Anova: Single Factor

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
Column 1	3	24.7	8.233333333	2.544533
Column 2	3	26.13	8.71	2.2923

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	0.3408167	1	0.340816667	0.140926	0.726421	7.70865
Within Groups	9.6736667	4	2.418416667			
Total	10.014483	5				

Cumulative BOD Removal (mg/ g of Peat)

2-day HRT

Column ID	Avg. 8.28 cm ³ /cm ² /day	Avg. 10.82 cm ³ /cm ² /day
Column 1	7.65	13.50
Column 2	5.51	5.80
Column 3	9.57	10.60

Anova: Single Factor

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
Column 1	3	22.73	7.576666667	4.124933
Column 2	3	29.9	9.966666667	15.12333

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	8.56815	1	8.56815	0.890278	0.398827	7.70865
Within Groups	38.496533	4	9.624133333			
Total	47.064683	5				

Cumulative BOD Removal (mg/ g of Peat)
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5-day and 2-day HRT

	Column ID	5-day HRT	2-day HRT
Avg. 8.28 cm ³ /cm ² /day	Column 1	6.42	7.65
	Column 2	9.42	5.51
	Column 3	8.86	9.57
Avg. 10.82 cm ³ /cm ² /day	Column 1	7.54	13.50
	Column 2	10.42	5.80
	Column 3	8.17	10.60

Anova: Single Factor

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
Column 1	6	50.83	8.471666667	2.002897
Column 2	6	52.63	8.771666667	9.412937

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	0.27	1	0.27	0.047303	0.832199	4.964591
Within Groups	57.079167	10	5.707916667			
Total	57.349167	11				

Cumulative TSS Removal (mg/ g of Peat)

5-day HRT

Column ID	Avg. 8.28 cm ³ /cm ² /day	Avg. 10.82 cm ³ /cm ² /day
Column 1	10.92	14.96
Column 2	15.28	16.71
Column 3	15.59	14.37

Anova: Single Factor

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
Column 1	3	41.79	13.93	6.8191
Column 2	3	46.04	15.34666667	1.481033

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	3.0104167	1	3.010416667	0.72539	0.442369	7.70865
Within Groups	16.600267	4	4.150066667			
Total	19.610683	5				

Cumulative TSS Removal (mg/ g of Peat)

2-day HRT

Column ID	Avg. 8.28 cm ³ /cm ² /day	Avg. 10.82 cm ³ /cm ² /day
Column 1	2.91	5.20
Column 2	1.40	1.32
Column 3	4.23	3.26

Anova: Single Factor

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
Column 1	3	8.54	2.846666667	2.005233
Column 2	3	9.78	3.26	3.7636

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	0.2562667	1	0.256266667	0.088845	0.780492	7.70865
Within Groups	11.537667	4	2.884416667			
Total	11.793933	5				

Cumulative TSS Removal (mg/ g of Peat)
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5-day and 2-day HRT

	Column ID	5-day HRT	2-day HRT
Avg. 8.28 cm ³ /cm ² /day	Column 1	10.92	2.91
	Column 2	15.28	1.40
	Column 3	15.59	4.23
Avg. 10.82 cm ³ /cm ² /day	Column 1	14.96	5.20
	Column 2	16.71	1.32
	Column 3	14.37	3.26

Anova: Single Factor

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
Column 1	6	87.83	14.63833333	3.922137
Column 2	6	18.32	3.053333333	2.358787

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	402.63668	1	402.636675	128.2094	5.03E-07	4.964591
Within Groups	31.404617	10	3.140461667			
Total	434.04129	11				

Total Operational Life (day)		
5-day HRT		
Column ID	Avg. 8.28 cm ³ /cm ² /day	Avg. 10.82 cm ³ /cm ² /day
Column 1	104	108
Column 2	108	101
Column 3	115	101

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Column 1	3	327	109	31
Column 2	3	310	103.3333333	16.33333

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	48.166667	1	48.16666667	2.035211	0.226851	7.70865
Within Groups	94.666667	4	23.66666667			
Total	142.83333	5				

Total Operational Life (day)		
2-day HRT		
Column ID	Avg. 8.28 cm ³ /cm ² /day	Avg. 10.82 cm ³ /cm ² /day
Column 1	82	93
Column 2	64	64
Column 3	93	82

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Column 1	3	239	79.66666667	214.3333
Column 2	3	239	79.66666667	214.3333

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0	1	0	0	1	7.70865
Within Groups	857.33333	4	214.3333333			
Total	857.33333	5				

Total Operational Life (day)

5-day and 2-day HRT

	Column ID	5-day HRT	2-day HRT
Avg. 8.28 cm ³ /cm ² /day	Column 1	104	82
	Column 2	108	64
	Column 3	115	93
Avg. 10.82 cm ³ /cm ² /day	Column 1	108	93
	Column 2	101	64
	Column 3	101	82

Anova: Single Factor

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
Column 1	6	637	106.1666667	28.56667
Column 2	6	478	79.66666667	171.4667

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	2106.75	1	2106.75	21.06399	0.000996	4.964591
Within Groups	1000.1667	10	100.0166667			
Total	3106.9167	11				

APPENDIX C

DIGITAL PICTURE OF EXPERIMENTAL SETUP

Figure C-1: Laboratory Experimental Setup

Figure C-2: Peat Column Experimental Set-up

Figure C-3: Spun Plastic Attached Growth Media in Aeration Chamber

Figure C-4: Samples of Raw, Aerated Leachate, and Column Effluents

Figure C-5: Top of a Peat Column after Clogging