Removal of Suspended Solids using In-Situ Filtration in Surface Water

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A Thesis

in

The Department

of

Building, Civil & Environmental Engineering

Presented in Partial Fulfillment of the Requirements
for the Degree of Master of Applied Science (Civil Engineering) at
Concordia University
Montreal, Quebec, Canada

April 2010

Your file Votre référence
ISBN: 978-0-494-67285-3
Our file Notre référence
ISBN: 978-0-494-67285-3

ABSTRACT

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Compromised water quality impacts many surface water resources worldwide. The decline in the water quality can be attributed to various pollutants discharged into water areas such as rivers, lakes and ponds. Most of the pollutants, such as nutrients, organic compounds, bacteria, which were released into the water areas, are adsorbed onto the surface of the suspended solids (SS) and settle to the bottom. Phosphorus (P) is considered as the controlling element in the propagation of eutrophication in water bodies. Algal blooms threaten lake water quality and in order to control their growth, removal of P along with the SS is essential.

The focus of this study was to improve water quality by removing SS and phosphorus through a pilot scale in-situ filtration tests. A nonwoven geotextile was used as the filter medium. The pilot-scale unit was set up at Lac Caron, located 75 km north of Montreal in Saint-Anne-des-Lacs, Quebec, Canada. Filtration tests using four different nonwoven filters were performed. A nonwoven filter with apparent opening size (AOS) of 150 μm and thickness of 0.3 cm was effective in removing SS concentration by 91%. The water quality improved in terms of SS and P removal rendering in-situ filtration as an effective treatment system or remediation technology for contaminated surface water bodies such as inlets, bays, lakes, and ponds.

Acknowledgements

I would first like to extend my sincere thanks to my supervisor, Dr. Catherine N. Mulligan for not only giving me the opportunity to be associated with a project that so closely matches my interests but also for providing me invaluable guidance and suggestions in accomplishing this project.

I also would like to thank Dr. Tomohiro Inoue for his guidance and help at very beginning of this project. A special thanks to Ms. Claire Therrien, our lab technician for all her support and help during my lab experiments. And also, I would like to thank all my fellow graduate students for providing assistance when needed.

My sincere gratitude extended to all the members of St. Anne Des Lacs association on behalf of Concordia University especially Mr. Real Bolduc for his great help to perform this research by providing necessary local resources.

I am thankful to my family for their love and support during my years of education. I would not have been able to accomplish what I have, without them by my side, every step of the way.

Lastly, my deepest thanks to my fiancée Sandeep Bharadwaj for all the undying support and encouragement he gave me, because without that I wouldn't have been able to step into the canoe all by myself to collect samples.

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CHAPTER ONE

INTRODUCTION

1.1 The Problem

Globally, water quality deterioration is growing as one of the leading environmental concerns affecting every single person on the earth. The decline in the water quality can be attributed to pollution entering surface water from municipal and industrial discharges, agricultural and urban runoff. In Canada, one of the major issues of concern for water quality is considered to be as nutrient enrichment. Nutrients create a problem in freshwater bodies when the concentration increases beyond the tolerance limits and is often referred to as eutrophication (Chambers et al., 2001).

In most of the fresh water systems, phosphorus (P) has been identified as the limiting nutrient for algal growth, and when excessive amounts of P enter water bodies, large quantities of noxious algae (blue green algae or cyanobacteria) and aquatic plants are produced resulting in algal blooms, loss of water clarity, nutrient rich sediments and loss of oxygen from bottom water which in turn accelerates phosphorus releasing processes (Carpenter et al., 1998). Furthermore, cyanobacteria can produce certain toxins that can kill fish and also pose threat to humans. In addition, snow melt and heavy rainfall can lead to high levels of suspended solids in freshwater systems that are rich in organic matter and nutrients. In general, suspended solids (SS) are organic and inorganic particles held in suspension which can adsorb several contaminants such as nutrients, bacteria and

heavy metals. These solids are considered to be a major portion of sediments at the bottom of the lakes (Fukue et al., 2008). Thus removal of SS not only improves water quality, but also removes nutrients adsorbed on solids which in turn reduce the environmental concerns associated with nutrients.

1.2 Justification

Many regulations and best management practices have been implemented to control the quality and quantity of pollutants entering the freshwater system. These practices will help to reduce the external loading of P into water (Environment Canada, 2004). In addition, after limiting the external sources, in-situ techniques have to be used to control the release of phosphorus from sediments. The techniques used for instance, precipitation using salts, in-situ capping, dredging have their own limitations such as cost-factor, pH maintenance, toxicity, incomplete removal, resupension of sediments which can further reinstate the problem (Charboneau, 2008; Kim et al., 2007; Mulligan et al., 2009). Thus remediation has to be done by keeping environmental conservation into account.

Recently a new, economical and innovative environmentally friendly technology was developed at Tokai University, Japan for removal of suspended solids and contaminants adsorbed on solids from water and sediments by in-situ filtration (Fukue et al., 2006). Filtration is one of the available techniques for removal of SS. This is because of its separation ability which makes it easy to remove contaminants by removing particles larger than the pore size of the filter media. Upon continuous filtration, SS will get trapped on the filter medium (in this case the filter media is a geotextile) and forms a cake on the top of the media. This newly formed filter will further help in trapping the contaminants adsorbed on to

solids thereby proving that in-situ filtration technology is an effective way to improve water quality in surface waters.

1.3 Objectives

The objective of this study was to improve the water quality by removing SS through pilot scale in-situ filtration tests in surface waters without causing any disturbance to the surrounding environment. In addition, another objective is to evaluate the ability of filtration to reduce the levels of other water quality parameters associated with, and influenced by suspended solids levels, such as phosphorus, total nitrogen and oxygen demand was also studied. Nonwoven filters with different apparent opening sizes (AOS) and thicknesses were used to evaluate this in-situ technique in a lake.

1.4 Scope

The research was carried out for removing contaminants by setting up a pilot-scale in-situ filtration unit at one of the stations in Lake Caron. It is possible that once the system is scaled up, it will require further optimization to deal with different depths and variable concentrations of SS and P since the rate of P release is sensitive to the meteorological conditions, especially flow rates, and substantial variations that can occur between the years.

1.5 Thesis Organization

This study is presented in five Chapters. The first Chapter provides an overview of the suspended solids and phosphorus as potential pollutants together with highlighting the

filtration technology as a viable means of decontamination. Study objectives and scope are also given in this Chapter.

Chapter 2 mainly postulates the previous work done related to the study under the topic of literature review. Main subjects discussed are suspended solids and its mode of entry to the freshwater systems, phosphorus, its form and sources, and its effect in terms of eutrophication. Filtration as a treatment technology is described in this chapter with a particular emphasis on the newly developed environmentally friendly technology. Methodology and results of the pilot scale study conducted at the lake and laboratory are presented in Chapter 3. In addition to explaining the methodology adopted and experimental setup, the chapter also focuses on problems associated with Lake Caron.

In Chapter 4, the removal efficiency of SS and P using different geotextile media on a pilot scale is investigated. The chapter also includes investigations done on other stations with respect to water quality. The correlation coefficients obtained for each pollutant removal is also discussed. All results and findings achieved have also been summarized in this Chapter.

Finally, the thesis is concluded with Chapter 5, which summarizes the complete work of the pilot scale studies carried out for the evaluation of SS and P removal. This chapter also discusses some recommendations for the future work.

CHAPTER TWO

LITERATURE REVIEW

2.1 Water quality deterioration

Water constitutes one of the important physical environmental parameters of life. It is also life's sustaining factor gifted by nature. Hence, water is precious for survival of plants, animals, ecosystems and humans and has a direct bearing on their health. However, in recent years the water quality of rivers, lakes and coastal oceans has been degraded from various pollutant inputs (Carpenter et al., 1998). These inputs are classified as point and nonpoint sources that lead to deterioration of both surface and ground water quality. Point sources are generally defined as the waste stream, either from municipal, industrial or waste disposal sites. In comparison, non point sources are termed as the inputs from the broader region such as urban and agricultural runoff, construction, recreational boating and logging (NRC, 1992; Carpenter et al., 1998). With the increase in human activities, water supply demand has elevated in the past few years resulting in water quality deterioration.

Various pollutants such as suspended solids consisting of both inorganic and organic particles and nutrients are carried away from land to lakes, rivers and other enclosed areas by rainfall, snow melt and human activities (Zucker et al., 2008). Most of these pollutants discharged into water areas are either adsorbed or absorbed on the surfaces of suspended solids resulting in the contamination of the solids. Furthermore, suspended solids (SS) with high organic contents can deplete the levels of dissolved oxygen in water

during the process of in-situ decomposition of organic matter affecting aquatic system (Ryan 1991). Low levels of dissolved oxygen lead to anaerobic conditions at the bottom water resulting in the release of nutrients from sediments (Inoue et al., 2009). Enrichment in nutrient concentrations specifically phosphorus (P) not only degrades water quality but also leads to eutrophication problems (Bolinder et al., 2000).

2.2 Suspended Solids

Generally, suspended solids are organic or inorganic particles that are held in suspension in the water (Fukue et al., 2006). Under natural conditions, all streams carry some SS either in the form of particulates or dissolved matter (Ryan, 1991, Yoshio et al., 2006). Also, as previously mentioned, the concentration of suspended solids in the water column can be enhanced by various anthropogenic activities leading to transport of contaminants from land to water. Suspended solids can adsorb various types of contaminants, such as nutrients, bacteria, heavy metals and other toxic substances (Fukue et al., 2006). An increase in the suspended solid concentrations affects the whole aquatic ecosystem. Several studies have been conducted in the past to understand the effects of SS on the aquatic ecosystem and the factors influencing them (Bilotta et al., 2008).

One of the prominent effects is seen is the decline in transparency of water thereby blocking the sunlight required for the photosynthesis of aquatic plants and phytoplankton (Masters., 1998, Patel et al., 2004). This reduces the dissolved oxygen levels required in the water column, thereby supporting anaerobic conditions at the bottom of the water body. In addition, low levels of dissolved oxygen lead to the death of fish and other aquatic invertebrates such as zooplankton and benthic invertebrates (Newcombe and

Macdonald., 1991). A high level of SS increases the organic matter in the water column. Nutrients, such as phosphorus and nitrogen are released from the sediments through the decomposition of the organic matter by microorganisms (Fukue et al., 2006). This factor is also influenced by the rate of sorption, desorption and transport of the pollutants between the two phases of soil and water and their interaction in the aquatic environment (Riley, 1975). The dissolution of nutrients into water can lead to eutrophication. Excessive inputs of phosphorus in the freshwater systems can dramatically increase algal biomass, thereby creating algal blooms which limit the recreational use of the lake, and occasionally producing cyanobacteria toxins, which further pollute surface waters. The abundance of phytoplankton, periphyton and macrophytes can be the result of the indirect effects of suspended solids which acts as a carrier of phosphorus in the water (Heathwaite, 1994). Therefore removal of suspended solids from water not only improves water quality but also removes various contaminants adsorbed on them (USEPA, 1994).

2.3 Phosphorus in the aquatic system

Nutrients are found naturally in freshwater bodies and are essential for life of aquatic flora and fauna. This includes nitrogen, phosphorus, carbon, oxygen, potassium, sulfur and calcium, collectively known as macronutrients as they are needed in relatively significant amounts. There are certain other nutrients whose requirements are at smaller quantities known as micronutrients which include iron, zinc, copper, manganese and chloride (Chambers et al., 2001). However, nutrients nitrogen (N) and phosphorus (P) are considered as principle nutrients because in the environment, they exist at relatively high

concentrations (Pierzynski et al., 1994). In most cases, phosphorus is targeted, because it is most often the limiting nutrient for plant growth in many freshwater bodies around the world and it controls the rate of aquatic flora biomass production (Uusitalo et al., 2001; Veith et al., 2005).

2.3.1 Forms of Phosphorus

Phosphorus (P) is an essential element in all forms of life and plays a vital role in plants by being actively involved in photosynthesis and energy transformations (Owens and Shipitalo, 2006). It is a highly reactive, multivalent, non metal of the nitrogen group and does not exist naturally in the elementary state (Chambers et al., 2001). In nature, although phosphorus exists usually as part of a phosphate molecule (PO_4), it is also found in organic form commonly referred to as organic-bound phosphorus and is usually bound to plant and animal tissue (USEPA, 1994). In general, rocks are considered to be the largest reservoir of P, because it is in these rocks that the phosphorus cycle begins in the environment. Through the process of weathering, phosphorus from rocks are also found in soil, water body sediments, and in water (Mckelvey, 1973). In aquatic systems, P occurs in two forms, particulate (PP) and total dissolved phosphorus (TDP), respectively. TDP can be further separated into dissolved inorganic and dissolved organic (DOP) components (Ellison et al., 2006). Dissolved inorganic phosphorous is also known as soluble reactive phosphorus (SRP), dissolved reactive phosphorus (DRP) and sometimes as orthophosphate (ortho-P). Collectively they are referred to as bioavailable dissolved P and include inorganic phosphate ions $HPO_4^{-2,}$ $H_2PO_4^-$ and PO_4^{3-} (House et al., 1995). Particulate P on the other hand, is bound to clay particles that are physically washed off

the fields and deposited wherever and whenever the water velocity is slow enough for the particles to settle to the bottom of the water column (Braskerud, 2002).

Although P occurs in many forms, aquatic plants typically require orthophosphate form of P for their nutrition. The inorganic form of P is more significant and it is directly utilized by aquatic biota (Environment Canada., 2004). Figure 2.1 shows the generalized transformations of P in aquatic environment. As these plants take in dissolved inorganic phosphorus, it is converted to organic phosphorus and becomes part of their tissues. Organic phosphorus is the form required by animals and they acquire it by eating either aquatic plants, other animals, or decomposing plant and animal material. During the process of excretion or death of plants and animals, the organic phosphorus they hold sinks to the bottom, where bacterial decomposition converts it back to inorganic phosphorus. This inorganic phosphorus gets back to the water column as a result of

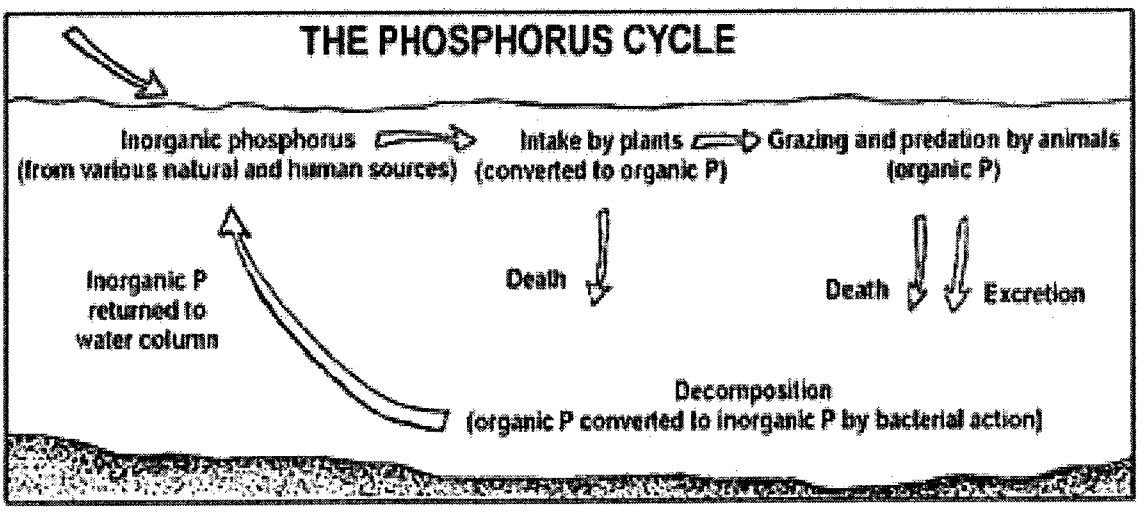


Figure 2-1 Generalized diagram of phosphorus cycle in aquatic environment (Adapted from: Spellman and Drinan, 1999)

resuspension at the bottom caused by water currents, animal and human activities. It is then taken up by plants and the cycle repeats (Spellman and Drinan, 1999). As Hutchison (1941) noted, the movement and cycling of P in lakes is not just influenced by biological processes but also by simple physical processes. However an increase in P inputs resulting from human activities will lead to an increase in algal growth, commonly known as eutrophication (Rigler, 1964). SRP is measured in order to check if phosphorus limits the growth of algae in the lake (Riegman and Mur, 1986). As the concentration of this fraction increases, it is inferred that phosphorus is either not needed by the algae or it is being supplied at rates faster than it can be taken up by the biota.

However, measurement of SRP as an indicator can be inaccurate, as the filtration of the water sample overestimates the concentrations of biologically available phosphorus (Fisher and Lean, 1992). This is because when a water sample is filtered using a 0.45 micron membrane, it excludes most particulates, leaving behind colloidal phosphorus and dissolved P form in the filtered fractions (Chambers et al., 2001). Hence, to avoid all these limitations, total phosphorus (TP) is chosen as a meaningful measurement of all forms of P in water (Wetzel, 2001). The analytical forms of phosphorus in the aquatic environment are as outlined in the Figure 2-2 (Chambers et al., 2001).

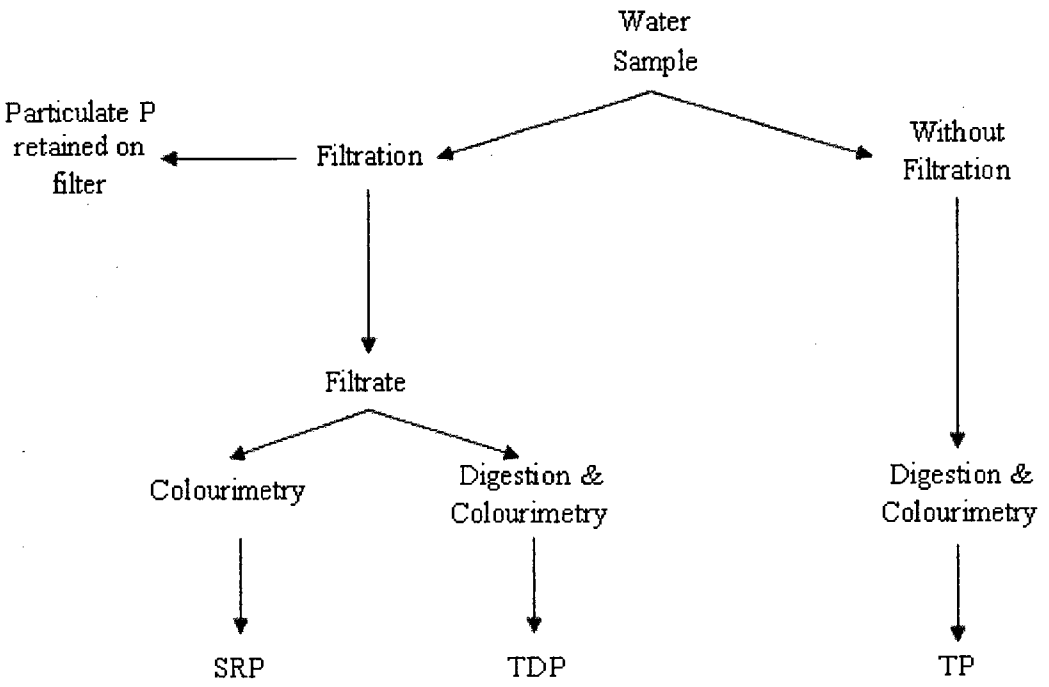


Figure 2-2 Analytical forms of phosphorus in the aquatic environment (Adapted from: Chambers et al., 2001)

2.3.2. Sources and fate of phosphorus

Phosphorus occurs naturally in the environment as a result of weathering of rocks, soil, animal wastes, and plant material. The loss of phosphorus into the land or leaching into the water was less, when the rivers and lakes were surrounded mostly by forest and wetlands. Natural vegetation plays an important role in binding or holding phosphorus in place. However, due to the dramatic increase of industrialization and intensive agriculture phosphorus concentration entering into water has increased in greater quantities (CCME, 1999). Phosphorus enters into an aquatic system through numerous sources and these sources are classified as internal and external sources or in other words, it is usually referred to as internal and external loading rate of phosphorus to the system. However,

the loading rate of P greatly varies with geology, pattern of land use, soil productivity and human activities (Environment Canada, 2004).

(I) External Loading:

As the name suggests, it's the quantity of phosphorus entering into the lake system at a given period of time by external sources or commonly known as anthropogenic sources. Inputs from these sources enter the aquatic system either by a definite point source or from a non point source. Figure 2-3 describes the external sources of phosphorus entering the water.

(a) Point sources

Point sources such as municipal sewage treatment plants and industrial effluent outlets are the main contributors of phosphorus entering water bodies. It is easy to identify and can be measured and controlled at a single point of discharge (Weaver, 1993; Chambers et al., 2001). Correspondingly, its contribution to overall water pollution is less and very simple to measure and regulate. On the other hand, non-point sources, being relatively more difficult to control, are the major cause of phosphorus loading to surface waters. Such pollutant inputs are generally derived from huge areas of land transported by surface runoff or by drainage flow (Carpenter et al., 1998).

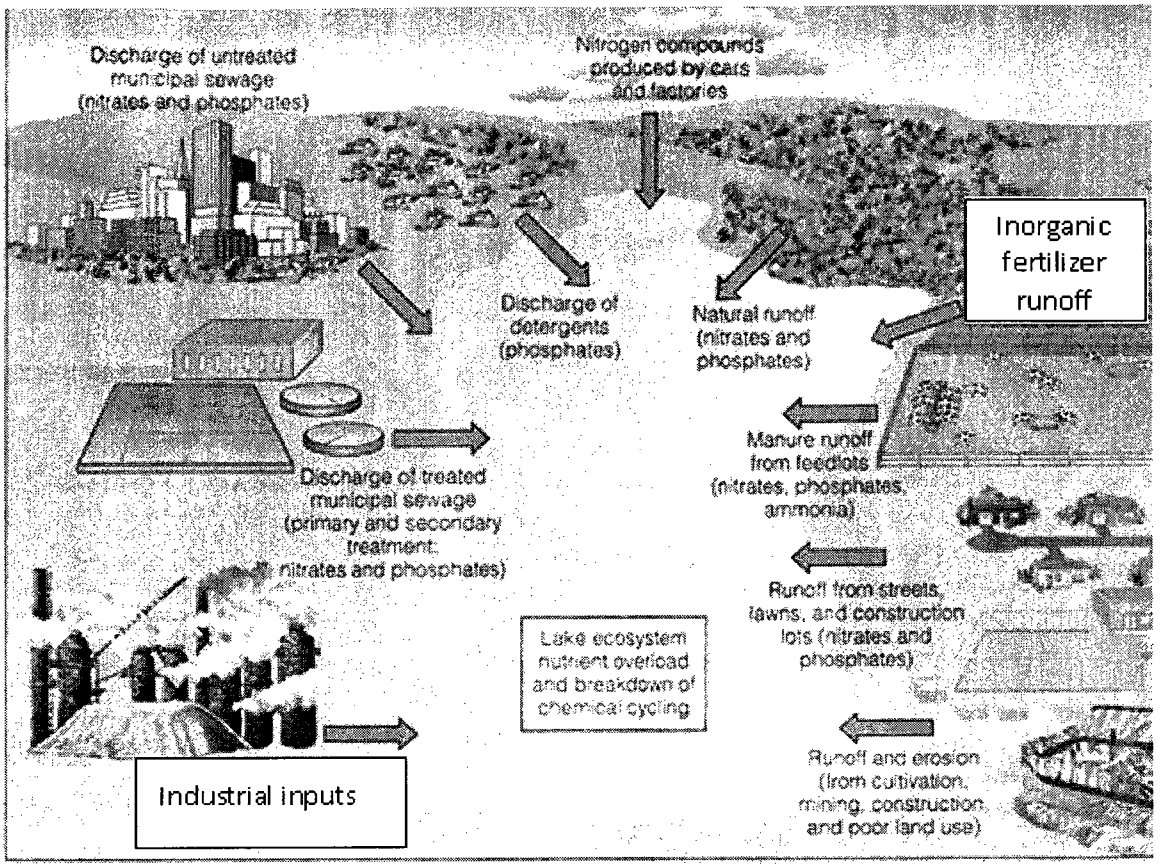


Figure 2-3 External sources of phosphorus into the aquatic ecosystem (Modified from: Soil and water conservative society, Halifax)

(b) Non point sources

In North America, phosphorus has been considered as the primary cause of pollution in aquatic ecosystems (USEPA, 1998; MENV, 2002), with an estimated 70% of the phosphorus entering lakes in Quebec coming from agricultural non point sources. Globally, increasing demand for food production leads to over fertilization of farmlands. Although fertilizers provide vital nutrients to crops, their excessive use poses threat to surface water in both short and long term. The addition of phosphorus in excess to crop utilization, leads to its accumulation in soil. The loss of phosphorus by surface runoff has been found to be directly related to the phosphorous content of the soil (Kadlec and

Knight, 1996). Agricultural runoff from such soils is one of the major environmental concerns, and the single largest contributing factor for the growing problem of surface water eutrophication (Carpenter et al., 1998; Gibson et al., 2000). In addition, urban activities such as wetland conversion, development of land, timber harvesting and construction sites have contributed significant amount of phosphorus into water (Heathwaite, 1994; Chambers et al., 2001). Overall, nonpoint sources are estimated to be responsible for more than 90 percent of phosphorous present in rivers and lakes. However, previous studies in the past have shown that even during the absence of significant external loading, phosphorus concentration in the aquatic system can still be high due to the phosphorus releasing capacity of the sediments in the water column which also explains the process of internal loading (Marsden., 1989; Holz and Hoagland., 1999).

(II) Internal Loading:

Sediments play a vital role in the phosphorus cycle by acting both as a sink and source of phosphorus to the lake (Baciu, 1993). By definition, sediments are the solids deposited at the bottom of the water body. Some of the sediments were SS formed by sedimentation. Practically all sediments are composed of variable quantities of organic matter, mineral grains, rock fragments, and carbonates and other precipitates, such as oxides of iron, magnesium and aluminum. Contaminants adsorbed on SS, when settled, contaminate sediments too. These contaminated sediments are toxic for the aquatic life and for humans (Fukue et al., 2006).

Both inorganic and organic particles are continuously deposited at the bottom of the lake and they are actively involved in the transformations. Precipitation and shells of diatoms

contribute to inorganic compounds in the sediment. Particulate phosphorus from the runoff and plankton debris sinks to the bottom and enriches the sediment with phosphorus (Holtan et al., 1988; Pettersson, 1998). In addition, the overabundance of organic matter caused by plankton debris settles to the bottom and decomposes by aerobic or anaerobic processes resulting in low levels of oxygen and anoxic conditions at the water-sediment interface. Under conditions of low or no oxygen at the bottom layer of water, P can be released from the sediments due to the chemical reduction of iron-phosphate complexes. This regeneration of P will lead to in-lake fertilization or internal loading of phosphorus and contributes more P for algal growth (Chambers et al., 2001). Figure 2.4 depicts the internal loading of phosphorus into the aquatic systems. The release of phosphorus is regulated by many factors, for example, the anoxic conditions, the microbial activities, redox interactions, which are dependent on oxygen supply, sorption mechanisms and the capacity of the elements, iron, aluminum, manganese, calcium, clay to bind and release phosphorus (Stumm and Morgan., 1996).

The potential phosphorus source in the surficial sediments is significant in comparison to the pools in the water column (Bostrom et al., 1988). This means that even if only a very small amount is released, it will have a significant effect on the phosphorus concentration in the lake water. Phosphorus leaves the sediment in a dissolved state mainly as a phosphate or as particles by resuspension. To leave the sediment in a dissolved state, phosphorus should undergo diffusion by physical, chemical or biological processes and to then be transported to the lake water (Pettersson, 1998).

In shallow lakes, internal loading of phosphorus and resuspension of sediments are the strong stabilizing factors for maintaining eutrophication over the years (Van der Molen et al., 1998). The primary response to a reduction in the external P load is a decrease in the concentration of P in the lake water. After the reduction of the external loads, the lakes start to respond to this reduction but to equilibrate with the new loading rates requires large intervals of time (Marsden, 1989).

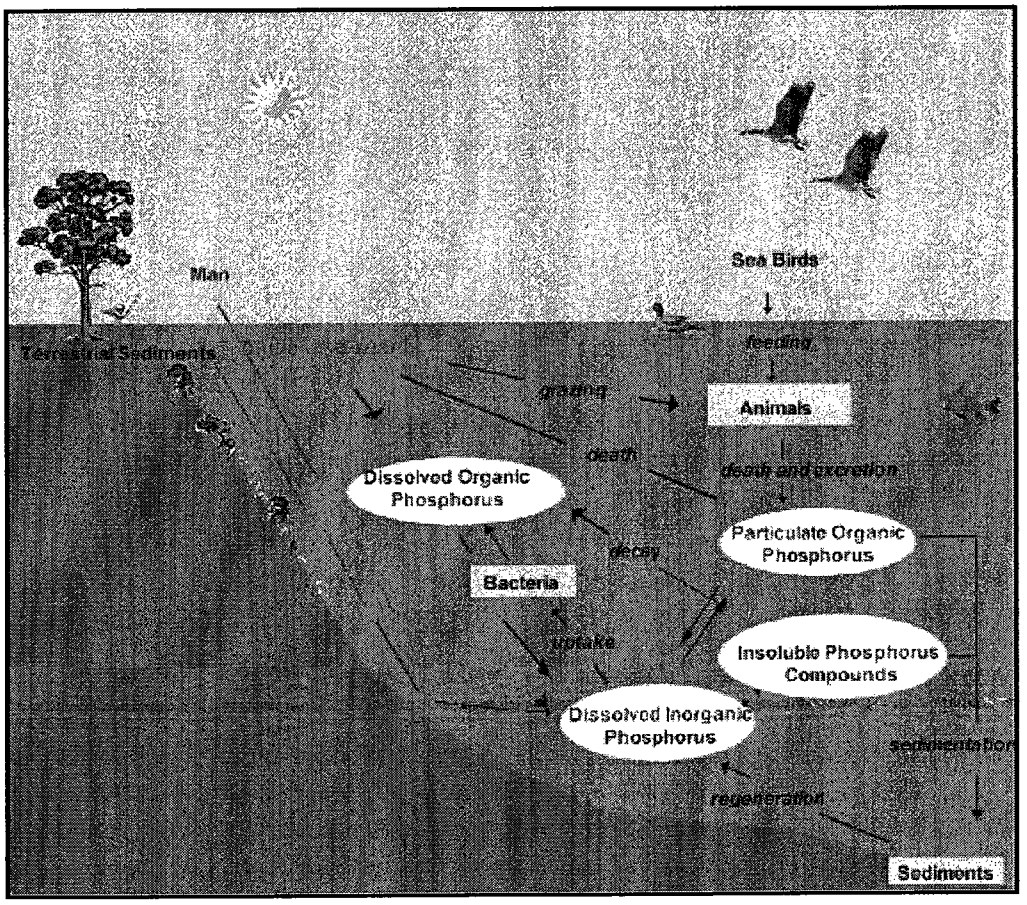


Figure 2-4 Internal loading of phosphorus in lakes (Modified from: Soil and water conservative society, Halifax)

2.3.3 Effects of phosphorus on aquatic environment

Nutrients are essential to all plant life on land and in the water for the production of their food and fibre. Although they are essential to life, their presence at high concentrations can be harmful. Phosphorus is considered as the primary pollutant. This is because lakes have a capacity to absorb nutrients but when this level is exceeded concentrations increase leading to obnoxious growths of algae and eutrophication (Chambers et al., 2001). Usually, rivers sustain higher loads of phosphorus than lakes without any significant changes in composition and biomass as phosphorus is often flushed from the system before it is utilized due to the faster movement as compared to lakes. Because of the slow movement of water in the lake, phosphorus bound to sediments, tend to settle out of the water column instead of being transported downstream (Ruth and Robin, 2003). The consequence is that a lake contains more available forms of phosphorus than rivers for large productivity (Hesse, 1964). An increase in phosphorus concentrations can cause undesirable effects, such as a decrease in biodiversity and aquatic biota, an increase in plant and animal biomass, and organic matter, leading to sedimentation and anoxic conditions (Mason 1991; Environment Canada, 2004). Phosphorus in water has no direct toxic effects on human and animals. However, secondary effects, such as eutrophication, algal blooms and oxygen depletion cause serious effects on both human and aquatic life (Carpenter et al., 1998; Environment Canada, 2004).

2.4 Algal blooms and Cyanobacteria

In most surface waters, such as lakes, rivers and ponds, the growth of algae or aquatic plants is controlled by the levels of P. The orthophosphate form of P is directly taken by

algae (Pierzynski et al., 1994). Algae produce organic matter that forms the base of a food chain, but excessive production has resulted in adverse ecological effects (Chambers et al., 2001). The algae form a thick layer at the surface of the water, limiting the presence of other species. In addition, when the algae die, they settle to the bottom of the lake, and microbial activity begins to decompose the algae. This rapid spike in microbial activity leads to a sudden drop in the dissolved oxygen content of the water body, causing bottom layer anaerobic. It also causes stress on the aquatic fauna, and often resulting in fish kills (Carpenter et al., 1998). In addition, a rapid population growth of algae results in 'algal bloom'. These blooms become particularly visible during calm conditions and warm temperature. Small gas bubbles present inside the algal cells cause them to rise to the surface of the lake and accumulate in scum, which is often not aesthetically appealing. This scum concentrates along the shore by wind and wave action where they begin to decompose. As the algae break down, pigments in the cells are released, often causing the water to turn a green, red or blue color. A coating, which looks like bright paint, is invisible on the water surface and on sand along the shore. Strong, foul odour is also produced when the algae die and decompose (Alberta Environment, 2003).

Cyanobacteria, often referred to as blue-green algae, are a group of many different species of bacteria and one among the most common types of bloom-producing algae. Certain species of cyanobacteria release cyanotoxins when the cells rupture or die and can be harmful to aquatic life if the concentration increases high enough, as they often do during algal blooms (WHO, 1999; Fleming et al., 2002; Environment Canada, 2001). Typically about 20 or more species of blue green algae are known for producing toxins during the summer. The blue green algal toxin microcystin – LR is currently used as an

indicator for the presence of other toxins (Environment Canada, 2001). These toxic chemicals can incur neurological damage in humans (Carpenter et al., 1998). In this circumstance the algal blooms are referred to as harmful algal blooms (HABs) (Smayda, 1997). The presence of HABs is increasing worldwide, ruining the aesthetics of a water body, potential risks of aquatic ecosystem sustainability and creating an unfavorable environment to mankind by limiting its use for recreation (Hudnell et al., 2009; Welch, 1992).

2.5 Eutrophication

In many regions of the world, intensive land activities, such as agriculture and land development tend to drastically increase phosphorus (P) loading into freshwater bodies resulting in algal growth and eutrophication. Globally, eutrophication has been identified as one of the leading threats to lake water quality (Harper, 1992). Eutrophication is a natural process that illustrates nutrient enrichment and lake productivity in terms of rapid growth of algae, which, in turn is responsible for changing the physical, chemical and biological properties of fresh water bodies. Enrichment of nutrients principally phosphorous, nitrogen and carbon to a lesser extent in fresh waters stimulates the growth of algae and phytoplankton, which leads to eutrophication (USEPA, 1990). As N and C are naturally present in a typical lake environment, P becomes the limiting factor for algal bloom. Ruth and Robin (2003) concluded that eutrophication as the natural process of lake aging and occur in 3 stages:

(a) The oligotrophic stage, which is characterized by low levels of biological activity and high levels of oxygen in the hypolimnion (bottom layer of the water)

(b) The mesotrophic stage, which is characterized by moderate levels of biological activity and beginning of declining oxygen levels following lake stratification.

(c) The eutrophic stage: at this point the lake is very productive, with algal blooms throughout the lake and increase in anaerobic conditions at the bottom of the water body.

Lakes with extremely high nutrient concentrations and excessive algal growth are termed as hyper-eutrophic. Chambers et al. (2001) compares this state of water to a pea soup.

2.5.1 Effects of Eutrophication

Eutrophication has many harmful effects on aquatic biota as well as humans and other organisms (USEPA, 1998; Wilson and Carpenter, 1999). According to EPA regulations, the threshold level of total phosphorus permissible in effluents entering lakes is 0.05 mg/L, however, concentration of phosphorus above 0.02 mg/L can stimulate the growth of algae (Sharpley et al., 2003). Extensive growth of algae is the most visible and remarkable change that occurs in water bodies (Anderson and Garrison, 1997). Along with deteriorating water quality, it may cause algal mats to form at the surface, often rendering the lake water unsuitable for human consumption, limiting the recreational use of the lake as visibility becomes insufficient for swimming and fisheries (Bochnia, 2001; Chambers et al.,2001). Algal blooms can also lead to anoxia. This effect appears due to the shortage of oxygen in fresh water when oxygen is consumed during decomposition of algae. Oxygen depletion due to decomposition of algae also causes a loss of habitat of desirable fish species (Carpenter et al., 1998). Other significant effects include increases

in suspended solids, decrease in transparency and reduction in aquatic flora and fauna species (Migliaccio et al., 2007).

Blooms of cyanobacteria or blue green algae are persistent symptoms of eutrophication (Smith et al., 1998). These blooms lead to severe problems including decrease in light penetration, foul odors and fish kills (Palmstrom et al., 1988). Cyanobacteria blooms are capable of producing water-soluble neuron and hepatoxins that affects the livestock as well as human beings (Lawton and Codd, 1991; Martin and Cooke, 1994). Thus, alleviation of nutrients especially phosphorus from water bodies is necessary.

2.6 Phosphorus management in freshwaters

Water contamination by excessive nutrient inputs is inevitable. This means certain regulations and guidelines have to be imposed in order to control flow of nutrients entering water system and to improve water quality. In some parts of Canada, a new concept, a Nutrient Management Plan (NMP) is introduced to control nutrients entering from agricultural fields (Environment Canada, 2004). This plan is aimed at considering issues such as, method and timing of nutrient application, agricultural practices, soil management, and nutrients loss via transportation to waterways. In addition, effective guidelines and approaches are essential for reducing phosphorus concentration in the lake water to control cyanobacterial bloom and lake eutrophication (Xiong and Peng, 2008). However, it is neither feasible nor desirable to set up a single guideline value for phosphorus levels in water since it varies widely according to the lake morphology, nutrient inputs and the ambient conditions for which aquatic communities are generally adapted to (Environment Canada., 2004). A guidance framework has been developed to

manage the levels of P in water. The framework uses trigger ranges, which are ranges of desired phosphorus level for freshwater systems. Table 2-1 shows the total phosphorus trigger values corresponding to the trophic status in the freshwater system.

Table 2-1 Total phosphorus trigger ranges for Canadian lakes and rivers (Environment Canada, 2004)

Trophic Status	Canadian Trigger Ranges of Total Phosphorus (µg/L)	
	Lakes	Rivers
Ultra-oligotrophic	<4	-
Oligotrophic	4-10	<25
Mesotrophic	10-20	25-75
Meso-eutrophic	20-35	-
Eutrophic	35-100	>75
Hyper-eutrophic	>100	-

Reduction of P from a point source is not effective due to the limitations of cost factors and high proportions of non-point P sources. Under these situations in-situ control methods provide the possibility to support or to accelerate measures for P removal (Ryding and Rast, 1991; Xiong and Peng, 2008). Direct chemical precipitation of phosphorus using iron and aluminum salts is considered as an important method in removing phosphorus from a lake (Cooke et al., 1993). These precipitants are generally considered as nontoxic and a long lasting method to reduce algal growth by limiting available phosphorus and trapping it as insoluble compounds that settle to the bottom of

the lake (Cook et al., 1993). However, this method has certain limitations such as cost factors and choosing appropriate salts for the treatment. In most cases, treatment with aluminum salts is preferred to iron salts on account of their insensitivity towards redox potential fluctuations at the sediment/water interface. But using aluminum salts is restricted only to buffered lakes with pH between 6 to 8 due to the potential aluminum toxicity especially in acidic lakes, and lakes with pH higher than 9.0 (Charboneau, 2008; Xiong and Peng, 2008). Wetland treatments have been used but their efficiency in removing P is not up to the mark (Coveney et al., 2002). In addition, remediation techniques for sediments are considered for phosphorus removal. In situ capping of sediments and dredging are the most commonly used methods to control P release from sediments. However, both methods have their own limitations to be used effectively due to cost factors, incomplete removal, sediment disposal, resuspension of sediments and deposition of new pollutants on the capped layer which will reinstate the problem (Kim et al., 2007; Mulligan et al., 2009).

In addition, current existing treatment methods for algae are not effective as they can impact non-target organisms and are short acting. Algal mats can be removed with a rake or a screen, but they tend to grow fast as they are pulled out. Algae is reduced when copper sulphate is added, commonly known as algicides, but it should be used with caution with regards to recreational activities and can be toxic to (WHO, 1999; Charboneau, 2008). New technology such as solar powered circulation (SPC) is designed to suppress the algal blooms but it was found to be effective only when used with addition of algicides or chemical precipitants which lead to further pollution (Hudnell et al., 2009).

On the other hand, as previously mentioned, SS has the potential to adsorb nutrients, bacteria, and other toxic materials which influences water quality. Therefore removal of SS not only improves water quality but also reduces the risk of eutrophication algae blooms. Filtration is one the available important techniques for removal of suspended solids (Fukue et al., 2006).

2.7 Total Nitrogen

Nitrogen is the most abundant element in the Earth's environment as N_2 gas, which makes up about 78 percent of the air we breathe. It is considered as a critical nutrient that is generally used by plants within the natural ecosystems and required by all organisms for the basic processes of life to make proteins, to grow, and to reproduce (Vitousek et al., 2002). Nitrogen is very common and found in many forms in the environment. Inorganic forms include nitrate (NO_3), the most common bioavailable form; nitrite (NO_2) and ammonia (NH_3), which are typically present at relatively low levels except in highly polluted situations and nitrogen gas (N_2) in the atmosphere. Organic nitrogen is found in the cells of all living things and is a component of proteins, peptides, and amino acids, which is generally less available to biota. The total amount of all these forms is represented as total nitrogen (TN) in the water sample (Gibbons et al., 1994). The **major sources** of nitrogen in the environment include (Muller et al., 1999; NPI, 1998; Tebbutt, 2002):

- Fertilizer is a major influence on nitrogen concentrations in the environment. Commercial nitrogen fertilizers are applied either as ammonia or nitrate, but ammonia rapidly gets converted to nitrate in the soil.

- Food processing industries, treatment plants, septic tanks and intensive livestock industries, such as poultry farms, are all industrial sources that can also contribute to total nitrogen emissions which will eventually end up in surface water and groundwater through rainfall.

- Organic nitrogen, which is a nitrogen compound found in living material, is found in soil, and in plant and animal material such as manure, sewage waste, compost and decomposing roots and leaves.

- Oxides of nitrogen are contained in exhaust fumes emitted into the atmosphere by cars, airplanes, trains and boats. These emissions are dissolved by rain and then enter streams, lakes and other water bodies.

- Surface runoff from farmlands and residential and commercial lawns contribute nitrate into storm drains, groundwater and freshwater systems.

- Animal waste and atmospheric deposition also contribute significant amounts of nitrogen to the environment.

2.7.1 Impacts on environment

Total nitrogen can have damaging effects on the environment and particularly on aquatic life. Nitrates in the soil result from natural biological processes associated with the decomposition of plant residues and organic matter. It becomes a concern to water quality when nitrogen in the soil is converted to the nitrate form. This is because nitrate is very mobile and highly soluble in water. Because of this nature, it is easily transported into surface waters such as ponds, streams and rivers and groundwater. Excess nitrate is not

toxic to aquatic life, but increased nitrogen may result in overgrowth of algae, which can decrease the dissolved oxygen content of the water, thereby harming or killing fish and other aquatic species (USEPA, 1994). When nitrate concentration exceeds 10mg/L in drinking water it causes major damage to human life by limiting the ability of red blood cells to carry oxygen. This condition is called methemoglobinemia or "blue baby" syndrome (nose and tips of ears appear blue from lack of oxygen) and is serious especially for infants as they lack the enzyme to correct this condition (CCME, 2009).

In freshwater systems, increased concentrations of TN along with the TP concentration also lead to toxic blue-green algal blooms which in turn lead to many serious problems as discussed in the eutrophication section. However, phosphorus is considered as the most common limiting nutrient for causing eutrophication since nitrogen can limit eutrophication only if its concentration is at least eight times more than that of phosphorus in water (UNEP, 2003). If the TN concentration exceeds 1.8 mg/L in the lake water, it is considered to be a eutrophic water according to the classification made in 1980's by Organization for Economic Cooperation and Development (OECD). They also classified lakes into oligotrophic and mesotrophic if the concentrations in water are in the range of 0.6 mg/L to 0.75 mg/L and 0.75 mg/L to 1.87 mg/L, respectively.

2.8 Chemical oxygen demand

Chemical oxygen demand (COD) indicates the pollution level of a water body as it provides an indirect measurement of organic material in water is highly correlated with phytoplankton concentration. It is the amount of oxygen required to chemically oxidize the organic matter present in water to CO_2 and water, by using a strong chemical oxidizing agent in an acidic

medium and expressed as mg/L (WQM, 1999). Studies have confirmed that the amount of oxygen consumption is related to the plankton density since microorganisms decompose organic matter with the help of oxygen (Boyd, 1982). It was proven that the COD concentrations remain higher at the bottom of water bodies, where organic matter concentration is high, as compared to the surface because of the aeration at the surface (Prasad and Qayyum, 1976).

From many years potassium permanganate ($KMnO_4$) was used as a strong oxidizing agent, but because its effectiveness varied widely, it was not able to oxidize all organic material effectively. To overcome this and due to the fact that potassium dichromate ($K_2Cr_2O_7$) is the most effective, inexpensive, easy to purify, and is capable of totally oxidizing almost all organic compounds, this chemical has been used to determine COD.

2.9 Surface Water Treatment

Increasing urbanization, industrialization and intensive agricultural activities have caused various pollutants entering in to surface water. The nature of these pollutants varies widely and hence only few methods exist for treatment and remediation of these large areas effectively. Most of the pollutants that enter water stream are either in form of inorganic or organic matter and are held in suspension or in solution known as suspended solids. Hence most of the treatment plants use suspended solids measurement as a water quality indicator (Tebutt, 2002). Measuring SS is an easy and inexpensive technique. Removal of suspended solids is generally achieved by filtration and or by sedimentation. However, filtration is considered as one of the most reliable techniques to remove SS (Fukue et al., 2006).

2.9.1 Filtration

Filtration is a physico-mechanical method used for separating solids from fluids, in water and wastewater treatment. It is commonly referred to as mechanical separation in industries for particle separation. Filtration is typically used as a polishing step for water that has been pretreated by flocculation and sedimentation in municipal and industrial wastewater applications. Filtration not only removes solids but to some extent removes turbidity, bacteria and color. The process of suspension is done through porous media, usually sand, to get clarity water (Tebbutt, 2002). In order to achieve this, various water filters have emerged over the centuries in response to the growing recognition of the need for pure and clean water to drink.

2.9.1.1 Filtration history

Apparently, it is believed that the history of water filtration started more than 4000 years ago. The first documented attempts for water purification go back to 2000 BC. The first methods that were used are boiling or placing hot metals in water, and passing that water through crude sand or charcoal filters to reduce visible particles and turbidity in water (Baker and Taras, 1981). In 1627, Sir Francis Bacon recorded the first experiments in water filtration using sand filters for purifying salt particles in sea water (Baker and Taras, 1981). With the discovery of the microscope, it gave an opportunity to view a whole new world of drinking water contamination and to distinguish and describe the life of a microorganism in a single drop of water that had been assumed to be clean (Wilson, 1995). As people began to understand the danger involved in water contamination, water filters using charcoal, sponge, and wool were widely used in the domestic limits.

In 1804, Robert Thom, a Scottish scientist, designed the slow sand filtration plant and the first large municipal water treatment plant was installed in Scotland in order to provide treated water to every resident (Baker and Taras, 1981). This revolutionary installation prompted the idea that all people should have access to clean drinking water. In London, Metropolis Water Act of 1852 was passed indicating that all water supplies should be purified by slow sand filtration plants (Binnie et al., 2002). This suggestion made the sand filters popular. The slow sand water filters designed were very large and required frequent and extensive cleaning. Because of the growing need for filtered water, scientists in the United States designed a rapid sand filter in the late nineteenth century (Baker and Taras, 1981). The rapid sand filter was cleaned by powerful jet streams of water, greatly increasing the efficiency and capacity of the water filter. Sand filters were combined with chlorination to eliminate waterborne diseases such as cholera, typhoid, and dysentery (Christman, 1998). In 20^{th} century, the growing demand for clean water resulted in installations of more water treatment plants among the developed countries. In the early 1970s, the US congress created history, by passing the Clean Water Act of 1972 (Outwater, 1996). It aimed at renewing the interest in water filtration and to have clean water nationwide. Today, millions of dollars are being spent to grant land for water treatment plants and environmental friendly waste treatment techniques for industrial wastes.

2.9.1.2 Filtration technology

Filtration is a process to remove fine solid particles from the liquid. This is achieved by passing liquid through porous media. In addition, in the water treatment plants, for producing high quality water, the water is treated by coagulation, flocculation and

sedimentation processes, lime or lime-soda ash softening with sedimentation (Michael and Clyde, 1987).

Finlay (1979) outlined several factors that affect filtration.

• Suspended particle size: existence of particles of large size cause an increase in filtration efficiency.

• Pore size: it determines the size of the particulate materials that can be trapped.

• Filtration velocity: increasing the velocity decreases the filtration efficiency.

• Chemical properties of the water and particles: to aid adsorption, a chemical filter aid may be added.

Filtration technologies can be classified as depth filtration and surface filtration. Figure 2-5 shows particulate material in the water versus pore size in the filtration method.

(I) Depth Filtration

In depth filtration, particle removal is achieved by passing water through a bed composed of an incompressible granular media. As the suspension flows through the filter bed, particles are transported to the surface, where they are removed by various mechanisms, including straining by mechanical contact, flocculation, adhesion, sedimentation, and diffusion. Sand, anthracite, and sand-anthracite mixtures are the most commonly used filtration media (Calinskaner et al., 1999). However, the basic principle remains regardless of the filter media used.

(II)Surface Filtration

Surface filtration is the most common type of filtration used for removing substances with the help of the filter media. During operation, the media captures the particles bigger than the pore size and deposit on to the surface of the media. Efficiency of this method is highly

related to the pore size of the filter and the particle size in the water body system (Salvato et al., 2003).

In addition, **membrane filtration** is used in many treatment plants as the advanced filtration method to produce water free from all substances including bacteria and other microorganisms, colloidal and particulate matter. In membrane filtration, a thin semi-permeable membrane is used to remove substances. Different types of membrane filtration processes exist, which are used in industrial applications such as water purification, wastewater treatment, pharmaceutical, medical, microelectronics, chemical processing, food processing, desalination, ion separation and material recovery. In all kind of membrane filtration methods, there is a need for a driving force which circulates the flow in the system (USEPA, 2005). The different filtration systems are microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO).

Microfiltration (MF): is the process with the largest pores and highest fluxes. Membrane pore size ranges from 0.1 to 10 micrometers and has the ability to remove major pathogens and large bacteria. It has been increasingly used for drinking water treatment purposes. However, it is not possible to remove organics with MF unless they are particulates and contribute to turbidity. In **reverse osmosis**, the membrane opening is very small, which can remove particles between 0.0001-0.001 micrometers in size (Gray, 2005), while in UF and NF the membranes are porous with pore sizes ranging from 0.01 to 0.1 micrometers and 0.001 to 0.01 respectively. **Ultrafiltration** is efficient in removing dissolved organic carbon and hence its usage is confined to industrial applications (Gimbel et al. 1993). Recently, **nanofiltration** was developed as it is suitable for low levels of dissolved solid solutions. Its application serves the purpose of

removing nuisance substances in surface and groundwater. In addition its main role is in desalination, along with removing natural and synthetic organic matter (Letterman, 1999).

2.9.1.3 Slow sand filtration

Slow sand filtration is the most common and oldest method available for producing clean water. Sand is the most frequently used filtering media and works efficiently under low turbidity conditions. In a slow sand filter, the filter bed is constructed of a medium with high surface area which can be colonized by suppressive micro-organisms. The water passes through the sand from top to bottom, leaving behind the larger particles on the top layers of the sand. Smaller particles of organic sediment remaining in the sand filter are eaten by microscopic organisms including bacteria and protozoan. The clean water exits from the bottom. Algae concentrations block the filter. When filters block, flow can cease. Hence, this filtration process requires a high volume of water for back washing and high capacity pumps to push the raw water through the filter and to backwash the filter. This makes the operation costly (Tebbutt, 2002; Salvato, 2003).

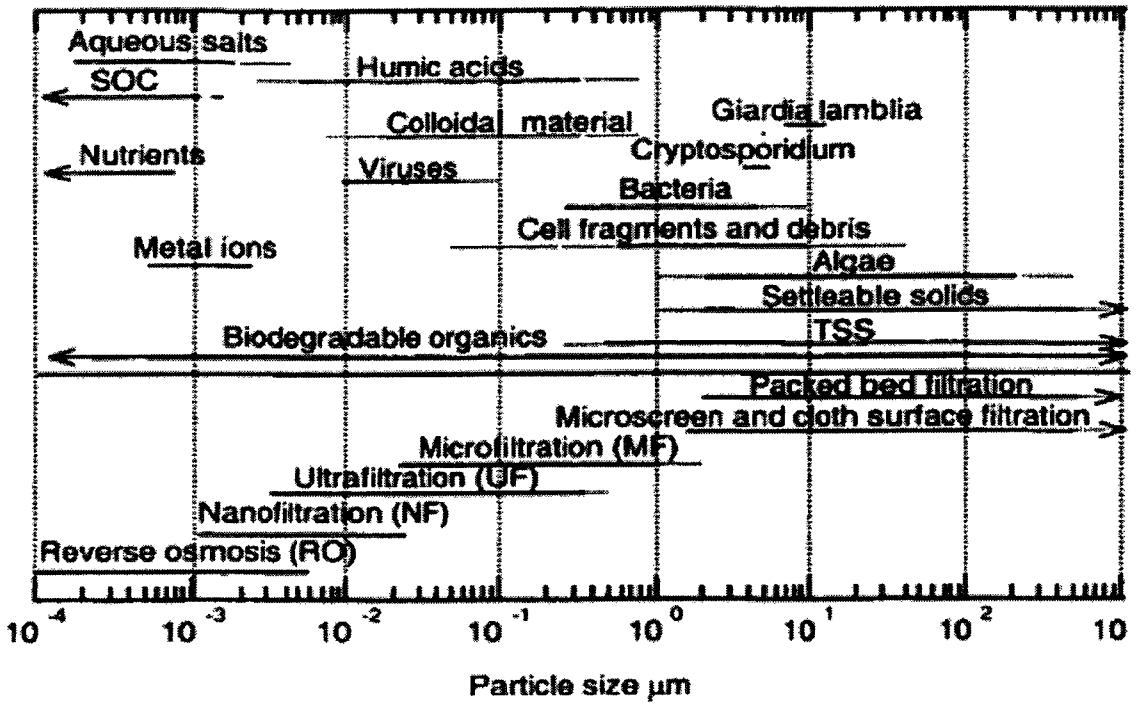


Figure 2-5 Different membranes and their removal ability (Levine et al. 1985)

2.9.1.4 Geosynthetics

Geosynthetics are thin polymeric manmade materials that are mostly used in geotechnical, geo-environmental and hydraulic applications (Bouazza et al., 2006). Soil improvement, separation, drainage and reinforcement are some of the important uses of these materials (Handbook of Geosynthetics, 2002). Geotextiles are classified in to two types based on the type they are manufactured (LaGrega et al., 2001; Koerner, 2005).

(a) Woven: are fabrics which have measurable opening sizes and have a visible construction pattern

(b) Non-woven geotextiles are felt like materials which are formed by a random placement of threads and they do not have any visible thread pattern (Koerner, 2005).

These materials are easy to handle and hence it's easy to use at various applications such as biofilters and in wastewater as baffles for biomass hosts (Korkut et al., 2006; Yaman et al., 2006).

2.9.2 In-Situ filtration

Modern technology provides a choice of treatment that can produce any quality of water from any given source, the limiting factor being economical rather than technical. Hence in situ remediation techniques are in growing demand to improve water quality. It's a recent technology that has been developed in Japan for water treatment (Fukue et al., 2006). Experiments have proved the ability to reduce the amount of SS, nutrients and heavy metals. In addition, this method can be used as new technology for lake restoration against toxic materials.

An experiment was performed in Kasaoka Bay in Japan by using barges with filtration system to treat the polluted water. This means that the filtration system can easily be moved in the area and treats only the polluted water that needs to be treated, which makes it a very cost-effective method. Figure 2-6 shows the filter used in Japan. It consists of a purification vessel which contained 38 filter units with a total area of 205 m^2. The results obtained clearly showed the decrease in concentration of SS from 30 mg/L to 2 mg/L.

Thus the new filtration method can be time saving and cost-effective method for improving water quality (Fukue et al., 2006).

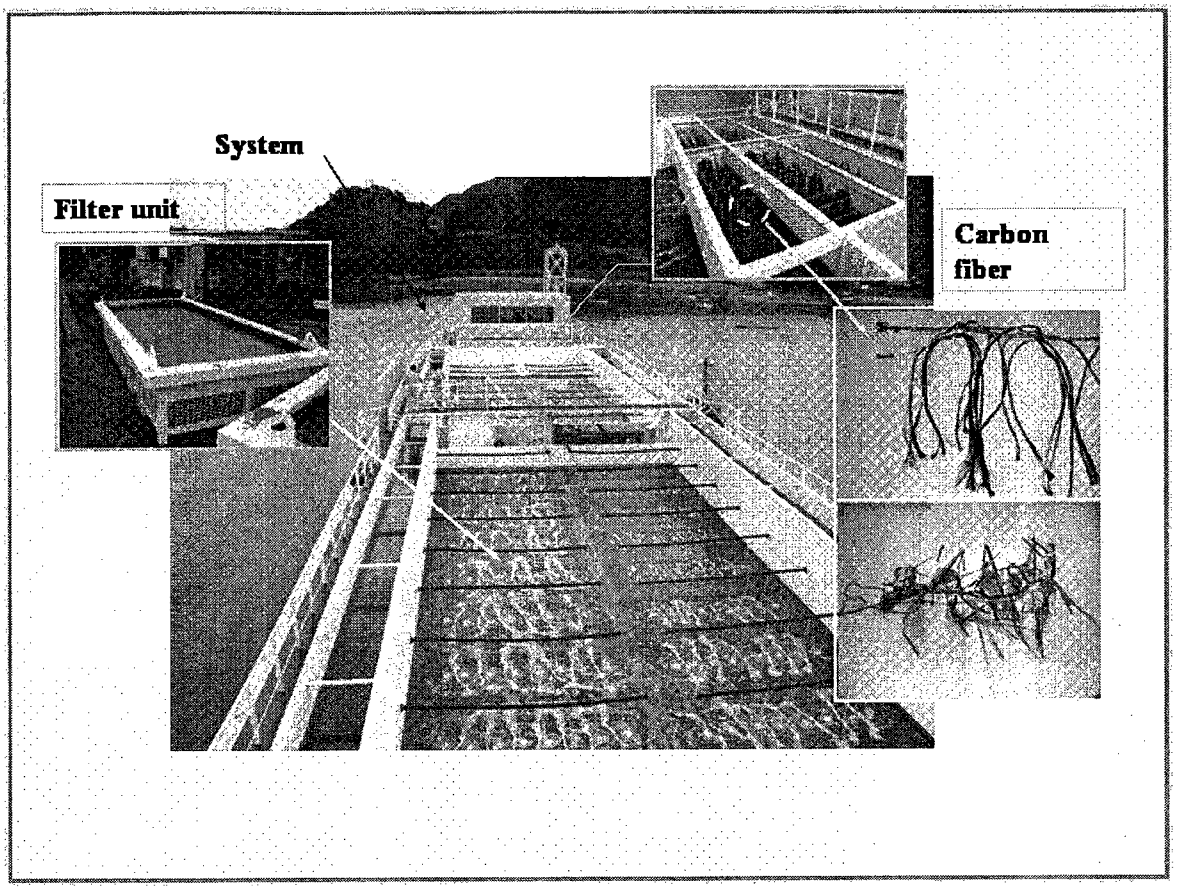


Figure 2-6 Filtration unit set up at Kasaoka Bay (Adapted from: Fukue et al., 2006)

2.10 Summary

As the quality of water declines, and regulations become even more stringent, new means of purification are needed that are ecologically sound and cost efficient. In-situ filtration of suspended solids provides a natural and cost efficient alternative to improving water quality. As mentioned so far, removal of solids not only improves water quality but also reduces the risk of algal blooms and eutrophication associated with the high levels of phosphorus concentration.

In this study, an in-situ filtration unit was set up at Lake Caron to improve the lake water quality by removing the suspended solids and reducing the levels of phosphorus associated with the algal growth over the past few years. The presence of cyanobacteria and potential toxins associated with it not only caused inconvenience to the local residents by prohibiting recreational activities but also in the future it might place an economic burden on the surrounding municipalities due to decreased property values and a subsequent remediation program. Thus, by means of in-situ filtration, Lake Caron can have a reliable and effective treatment technology through SS reduction without adding any further chemicals which might lead to further contamination.

CHAPTER THREE

MATERIALS AND METHODS

The release of contaminants into the environment must be minimized as much as possible. Phosphorus is recognized as the principal cause for deteriorating surface water quality in Québec. Increase in P load and suspended solids concentration results in eutrophication which is a leading problem in North America and thus making its control of primary importance.

The main goal of this research was to study the in-situ filtration process for treating lake water. It is a new process that has been developed in Japan and is gaining recognition as a promising solution for treating surface water, for their advantages like low-maintenance and effectiveness. This study also focused in removing suspended solids and other pollutants attached to them. The excessive algal growth due to high nutrient concentrations and growing concern over the deterioration of water quality in Lake Caron resulted in several studies for improving the water quality by setting up a pilot scale filtration unit.

3.1 Lake Caron and its Morphology

The filtration unit was set up at Lake Caron (45° 50' 28" N 74° 08' 50" W), a sector in the municipality of Saint-Anne-des-Lacs, located 75 km north of downtown Montreal in the region of Laurentian Mountains, Quebec (Figure 3-1).

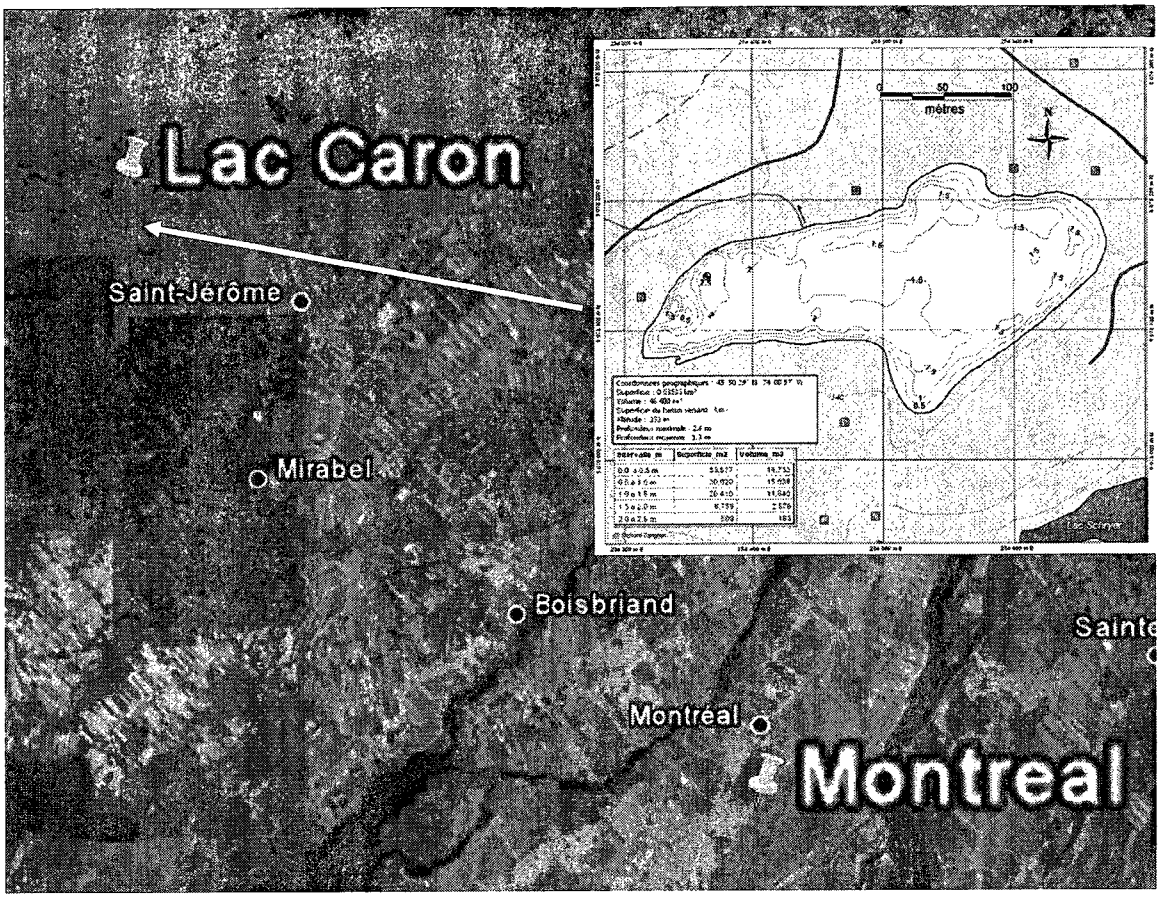


Figure 3-1 Location of Lac Caron with reference to Montreal (Inset: Lac Caron Topography) (Source: Google Maps, www.abvlacs.org)

Natural precipitation, surface runoff and snow melt are the only known water resources for Lake Caron. According to the municipality, it was a natural shallow pond that collected rain water. In the 1960's, the municipality of Ste. Anne des Lacs took an initiative to increase the surface area of the pond and declared it as a lake. The surface area measured was approximately about 35,330 m^2 and with a capacity of 50,200 m^3. The average depth is about 2.6 m in most parts of the lake and 0.5 m in the shallow parts [Refer to Appendix A]. The lake is frozen usually by October until May when the snow starts to melt during the early warm spring days. During the summer days, the discharge from the lake involves two natural phenomena which are infiltration and evaporation. In

some cases, when the water level in the lake exceeds a certain level, the water will flow out of the lake at some points by lowering the height of the lake walls. The lake is surrounded by wild trees and some private houses around the lake shores. Since the majority of the properties are used as country summer houses, only a few people live there throughout the year. In summer, people not only enjoy recreational activities such as pedal boating, canoeing and kayaking, but also practice some activities such as gardening and lawn mowing around the lake.

3.1.1 Problems of Lake Caron

Lake Caron is an artificial lake with great scenic beauty. However, this aesthetic beauty only remained until the Ministère du Développement Durable de l'Environnement et des Parcs (MDDEP), Québec noticed the first blue-green algae blooms in 2007. In the year 2008, the lake association approached Dr. Mulligan to investigate the lake water quality. According to the studies conducted, high concentrations of nutrients and suspended solids were observed. In addition, the MDDEP confirmed the presence of blue green algae and potential cyanobacteria toxins in the water and classified them into category 1.

In the year 2009, although the quality of the lake did not change significantly in the early summer, green particles were seen in suspension. Since the water temperature remained very low at around 16°C until the month of June, no such blue-green-algae break outs were noticed. However, as the concentration of phosphorus and suspended solids started increasing, aquatic plants started floating on the surface of the water in the shallow parts of the lake. As the water temperature increased in the month of July, sudden algal blooms were noticed in most parts of the lake leading to bad odor and a huge green mass floating

on the water. This indicated high nutrient concentrations in the water, mostly due to the surface runoff from the lake banks and forest around the lake. The runoff contributes to high loads of organic material (wood pieces and dead leaves) which settled at the bottom of the lake deteriorating both lake water and sediments. There might be a possible contamination with household detergents from the septic tanks. Figure 3-2 illustrates the changes in the condition of the lake from July to August 2009.

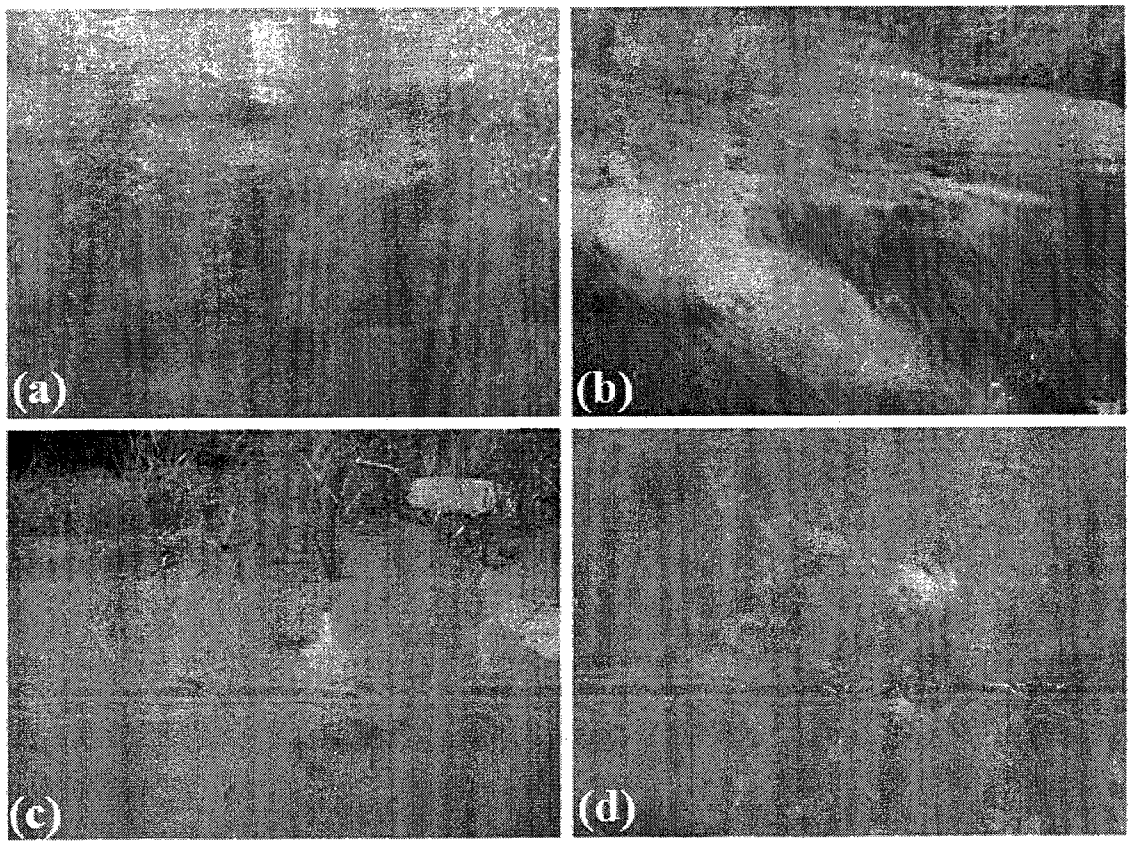


Figure 3-2 Changes in lake condition (a) early July, (b) late July, (c), (d) August 2009

With growing concern of the lake quality, MDDEP conducted various tests on cyanobacteria and for the presence of their potential toxins. The cyanobacteria count and their potential toxin produced counts ranged between 2000 cells/ml to 2,000,000 cells/ml

during the months of August to December 2009. They were classified into category 2a, 2b, 2c respectively. This means no public intervention with the lake water, such as drinking, swimming, leaving animals near the water, or even using water for gardening and lawns [Refer to Appendix B, 1-5].

3.2 In-Situ filtration

Upon agreement of the local citizens, preliminary in-situ experiments were conducted to determine the performance of the filter unit in November 2008. However, the experiments were stopped within a week due to the weather conditions. In the year 2009, the in-situ filtration tests started from the month of August and stopped until the lake was frozen in the month of November. The cylindrical filtration column made of plexiglass with an internal diameter of 20 cm and a height of 20 cm was used at the top of the base to hold water and support hydraulic head of 18 cm above the filter. A square shape base, with a circular hole at its center with the exact size of the filter was used as the filter holder. The whole unit was resting on a plastic tank from Nalgene with a 51cm height and an inside diameter of 34 cm and a capacity of 46.5 liters. Figure 3-3 shows the filtration set up. There was a hole placed at the height of 18 cm of the cylinder which acted like an emergency spillway. It would over flow when the head above the filter exceeds 17 cm.

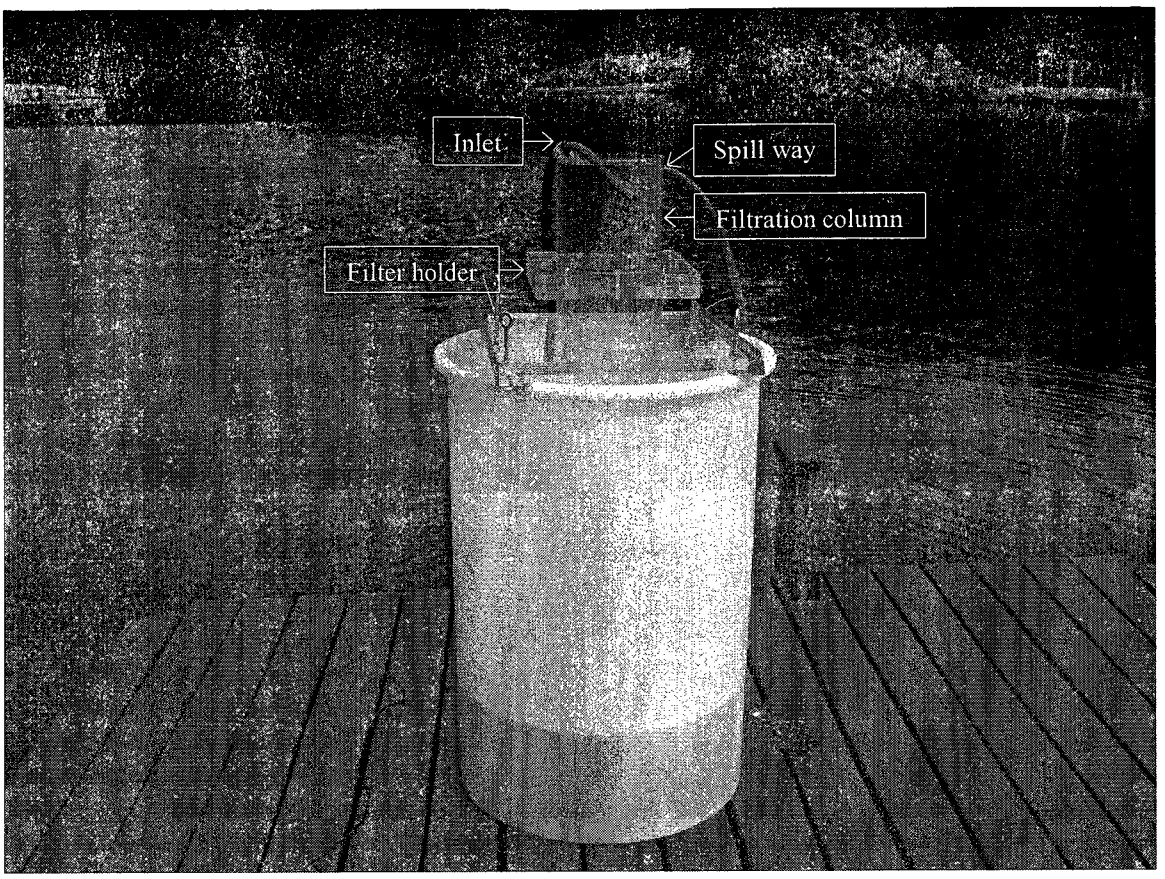


Figure 3-3 In-Situ filtration set up at Lake Caron

3.2.1 Sampling and storage

The water from the lake was directly pumped into the filtration column using a pump with a maximum capacity of 10 L/min. This flow rate was maintained constant throughout the study. Two samples were collected every day throughout the 80 day period of the filtration tests, between 9 am to 12 pm using 500 mL acid washed Nalgene bottles which were initially rinsed several times with lake water and filtrate respectively. Of the two samples collected, one sample was manually collected from the lake at a depth of 30cm and was labeled as "before filtration" to indicate the lake quality at the time of sampling. The other sample was the effluent directly drained from the filter labeled as

"after filtration". Samples were then immediately transported to the laboratory using an ice packed cooler to avoid any temperature changes which may cause chemical or biological reactions. After the samples were brought to the laboratory, 50mL of each sample was filtered to an acid washed Nalgene bottle using a 0.45 μm filter to immediately analyze the samples for SRP and TDP. The remaining samples were then stored in an incubator at a temperature of 4°C.

In addition, water samples from other shallow parts of the lake were also analyzed on a monthly basis. The stations were divided into Station 1, Station 2, Station 3, Station 4, Station5, Station6 and Station 7 respectively. The unit was set up at Station 6. The chosen sampling points are as shown in the Figure 3-4.

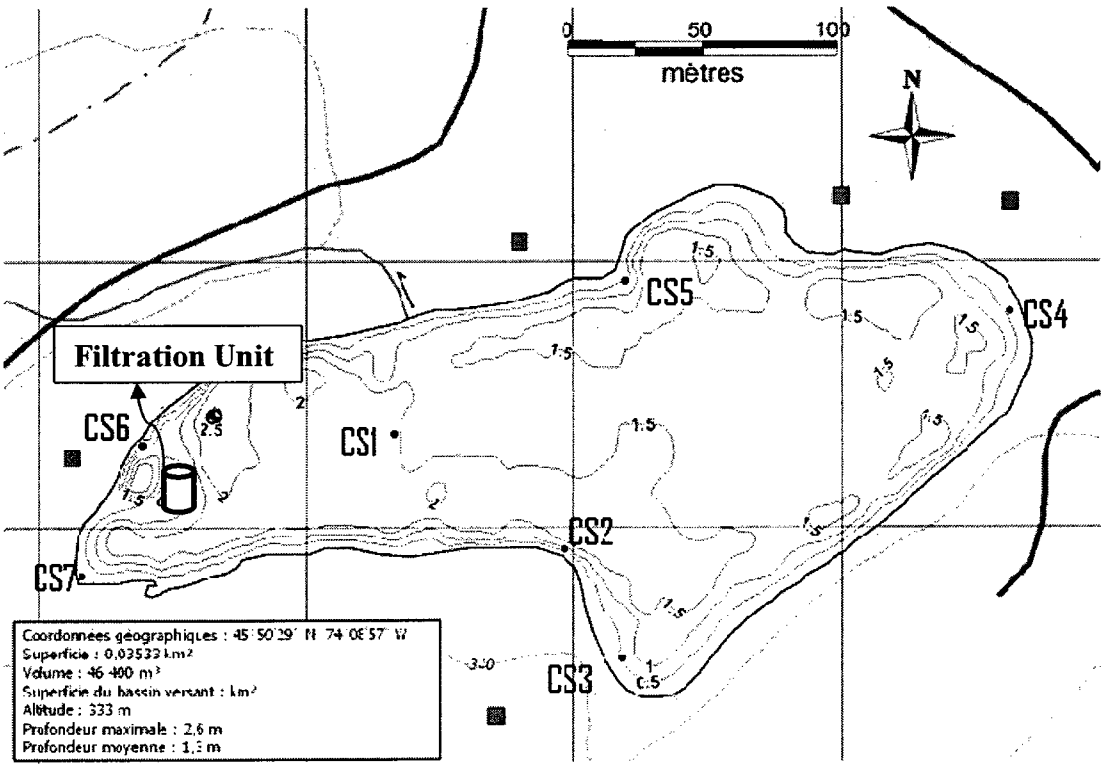


Figure 3-4 Lake Caron sampling points (Adapted from abvlacs.org)

3.2.2 Filter media

A nonwoven filter was used as a filter medium during the filtration process. Filters were obtained from Layfield Environmental Systems and Checkmate Geosynthetics. Filters used from both the companies were of the same type but with different apparent opening sizes (AOS) and thickness. As the name implies, AOS is the apparent maximum pore size of the geotextile. Table 3-1 describes the properties of the geotextiles used. The model number LP-12 was obtained from Layfield and GTX series from Checkmate.

Table 3-1 Geotextile properties (Source: Layfield Environmental Systems, Checkmate Geosynthetics)

Model number	AOS (μm)	Thickness (cm)	Permittivity (sec^{-1})
LP-12	150	0.20	1.00
GTX – 200	125	0.24	1.41
GTX-250	150	0.30	1.40
GTX- 300	125	0.36	1.41

After referring to the previous studies, 2 layers of filters were used throughout the filtration process. However, in one case 5 layers are used, just to compare filtration variation. This is further explained in the coming chapter (Section 4.2.1.2). The filters were cut in circular shape with a diameter of 22 cm. The basic concept of this filtration is to form a filter cake on the surface of the geotextile by separating the SS from the water which are larger than the opening size of the filter. The newly formed filter will further

reduce the levels of SS by trapping smaller particles which in turn can reduce other contaminants by the process of adsorption.

3.3 Analytical Measurements

3.3.1 Suspended solids

Suspended solids measurement indicates the amount of solids suspended in the water. The ASTM method (2540-D) was used to measure suspended solids in the water. The raw sample was well mixed before pouring into the graduated cylinder. By means of a vacuum pump (Figure 3-5), 100 mL of water sample was filtered through a pre-weighed 0.45μm filter. The dissolved materials passed through the filter leaving behind the particulate matter on the filter. The filters were then dried in an oven at 105°C for about one hour, cooled to room temperature in a desiccator and then weighed. The final weight (filter paper plus retained solids) in mg/L was calculated by subtracting the initial weight of the filter paper from the final weight of the filter paper and dividing by the volume of water that was filtered. Equation 3-1 shows the calculation for SS.

$$\text{Suspended solids (mg/L)} = \frac{((W_f - W_i) \times 1000)}{V_s} \qquad (3\text{-}1)$$

Where,

W_f = The final weight of the filter paper (mg)

W_i = The initial weight of the filter paper (mg)

V_s = Sample volume (mL)

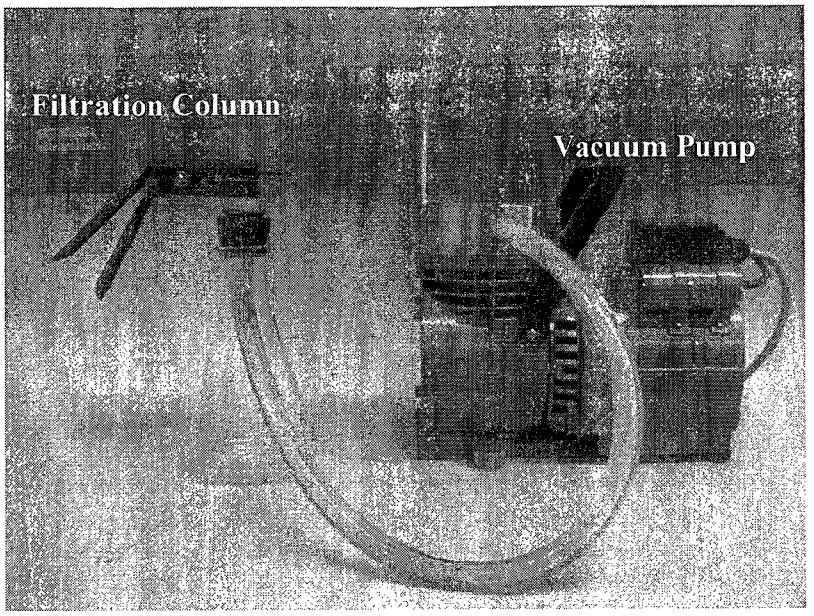


Figure 3-5 Suspended solids separation using a vacuum pump

3.3.2 Phosphorus

Water samples collected from both before and after filtration were analyzed for total phosphorus (TP), soluble reactive phosphorus (SRP) and total dissolved phosphorus (TDP) respectively. As mentioned earlier, filtered samples were analyzed for SRP, TDP and unfiltered samples were analyzed for TP. All the analysis were carried out using HACH TNT plus 843 test kits according to the ascorbic acid method as published by HACH™ in the water analysis book (Method 10209 Reactive; Method 10210 Total) with the detection range of 0.05–1.50 mg/L PO_4–P. To measure TDP and TP, 2 mL of filtered and unfiltered samples were used for digesting the samples with strong acid at a high temperature of 100°C for one hour to oxidize the organic matter and to convert condensed, organic and particulate forms of P to orthophosphate form of phosphorus. After cooling the sample, molybdate and antimony solution was added to dilute the ortho-

P solutions in an acid medium to form antimonyl phosphomolybdate complex, which was further reduced by ascorbic acid to form to phosphomolybdenum blue. The samples were then measured at 890 nm using a DR2800 spectrophotometer (Figure 3-6).

TDP was measured in order to find out if any particulate P was present in the water sample. It was found that only traces of particulate P were present after calculating the difference between TP and TDP. Since the measurement is of the least significance, the values of TDP and PP are not mentioned in this thesis.

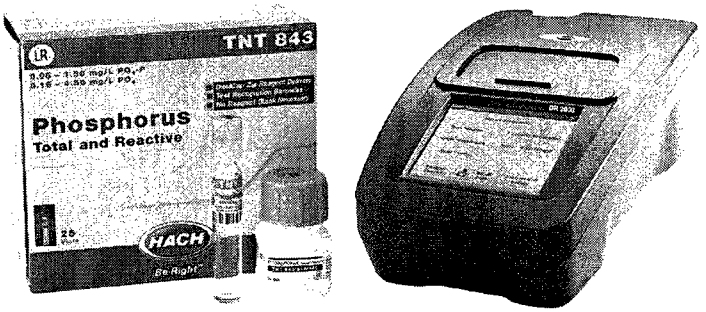


Figure 3-6 HACH™ DR-2800 Spectrophotometer used for analyzing TP and SRP

SRP was analyzed using 2mL of filtered sample but without any digestion procedure since this test requires only colorimetry. More emphasis was given to SRP measurement, as this fraction of TP represents the available form of phosphorus for plant growth.

In addition, the accuracy check was performed for total P and SRP methods by using 2 mg/L of standard phosphate solution in place of sample provided by HACH Company. Also, to check the test kits precision, some of the samples were reanalyzed according to the APHA methods (4500-P) for phosphorus and only a marginal error of 3% was found.

3.3.3 Total Nitrogen

Total nitrogen is the most common form of nitrogen that is measured, since it represents all forms of nitrogen present in the water sample. The persulfate digestion method was used to determine the total amount of nitrogen present in a sample. Analysis was carried out using HACH TNT plus 826 test kits with the detection limit between 1 to 16 mg/L, according to the method 10208 as specified in HACH™ water analysis book. Inorganic and organic bonded forms of nitrogen are oxidized to nitrate by digestion with peroxodisulphate at temperature of 100°C for one hour. The nitrate ions react with dimethylphenol in a solution of sulphuric and phosphoric acid present in the vials to form nitrophenol. After leaving the sample to cool to room temperature, the samples were ready to measure at 345 nm using DR2800 spectrophotometer (Figure 3-6).

3.3.4 Chemical oxygen demand

The dichromate chemical oxygen demand (COD) test was used to measure the amount of oxygen required to chemically oxidize organic matter. Measurements were done using HACH TNT™ plus 820 test kits according the USEPA reactor digestion method (method number 10211) as specified in HACH™ water analysis book. This method generally applies for water and surface water quality studies with the ability to measure COD in the range of 1-60 mg/L.

Samples for COD measurement were analyzed immediately as they were brought to laboratory. 2 mL of the sample was used for the analysis. Each vial contains sulfuric acid, potassium dichromate, sulfamic acid, and silver sulfate as the catalyst. After shaking the samples with the reagents, the vials were kept in the reactor at a temperature of 150°C for

120 minutes HACH™ DRB 200 reactor (Figure 3-7). Potassium dichromate presents in the vials acts as the oxidizing agent and silver compounds present act as catalyst to promote the oxidation action reducing the dichromate ion to green chromic ion. The amount of chromium ions remaining was measured. The vials remained in the reactor for about 20 minutes until it cooled down to temperature of 120°C and then about 25-30 minutes outside the reactor to reach room temperature for measurement. Samples were measured using a DR2800 spectrophotometer (Figure 3-6) at 348 nm.

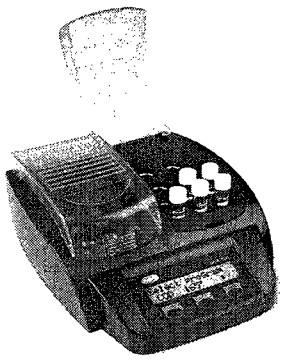


Figure 3-7 HACH™ DR-200 Reactor

3.3.5 Total coliform level

From the public health point of view, the bacteriological quality of water is an important parameter to be monitored since the freshwater systems are used for various activities such as swimming, drinking and other recreational activities. Municipal wastewater, agricultural runoff usually contains microbes that pose a risk to human health. The most commonly tested bacteria indicators are total coliforms, fecal coliforms and *Escherichia coli.* Total coliforms are a group of bacteria that are widespread in nature. However, they can occur in human feces, but some can also be present in animal manure, soil, and

submerged wood and in other places outside the human body (USEPA, 1997; MDDEP, 2002).

In this study, the presence of total coliforms in the lake water were measured using Coliplate™400 test kit provided by Bluewater Biosciences Inc. The test is designed to meet regulatory guidelines for surface water, recreational water and wastewater. The kit is based on 96-well microplate format with no sample dilution requirement. The following steps were followed for quantitative measurement of total coliforms.

- A stream of sample was gently poured over the wells directly from the sampling bottle, after removing the microplate lid.
- Once all the wells were filled, the air bubbles were dislodged by gently tapping the sides of the microplate. The excess sample remained on the plate.
- This excess sample was drained off by gently tilting the plate by a small angle and tapping the sides.
- The microplate lid was replaced and was incubated for 24 h at a temperature of 35 °C.
- The results were interpreted by placing the incubated microplate on a white surface and counted the number of wells which turned blue.
- The positive reaction of the wells turning blue corresponded to the presence of total coliform and the number of wells showing positive reaction indicated the most probable number (MPN) for total coliforms in 100 mL of water sample. The MPN table was provided by the manufacturer.

3.3.6 Water parameters

Dissolved oxygen (DO), pH, oxidation-reduction potential (ORP) and temperature data was also collected every day to check if the variations in any of these parameters would have influenced in the P exchange between soil and water surface or growth of algae etc., thereby affecting P loading into the water (Lijklema, 1980). These data were collected using a Hanna portable multi parameter meter (Model Series HI 9828, Hanna Instruments) with corresponding probes. All probes were calibrated and stored according to instrument specifications as mentioned in the instruction manual (HI series, 2006).

3.3.7 Measurement of TP retained on the filter

The following steps were followed to measure the amount of total phosphorus that was retained on the filter medium (GTX- 250, filter 7) after the filtration test was completed:

- The filter was washed twice using deionized water until all the solid particles attached to the filter was removed by the action of rubbing.
- This mixture (solid particles + water) was kept in a fume hood for air-drying at a temperature of about 22 - 24°C until the water was evaporated. It took about 1.75 days to evaporate completely leaving behind the solid particles.
- The solid particles were then crushed and it was ready to use for measuring the amount of total phosphorus present in it.

To determine the TP in the dried sample, perchloric acid digestion method was used as recommended in the APHA (4500-P) methods for phosphorus analysis. 1 gram of air dried sample was placed in a 250 mL volumetric flask for digestion with 20 mL of nitric

acid followed by 10 mL of perchloric acid unti the boiling sample color changed into white along with the appearance of white fumes of perchloric acid. The total time of digestion was approximately 45 minutes. After cooling the mixture, 1 drop of aqueous phenolphthalein solution was added, followed by 6N sodium hydroxide solution (NaOH) until the solution turned pink. The volume was brought to 250 mL using distilled water.

Mixed reagent was used to analyze TP. To prepare 100 mL of the reagent, 50 mL 5N sulphuric acid (H_2SO_4) (this solution was prepared by diluting 70 mL concentrated H_2SO_4 in 500 mL of distilled water) was added to 5 mL of potassium antimonyl tartrate solution, $K(SbO)C_4H_4O_6.1/2H_2O$ (dissolving 1.3715 g of $K(SbO)C_4H_4O_6.1/2H_2O$ in 500 mL distilled water), 15 mL ammonium molybdate solution (prepared by dissolving 20 g of $(NH_4)_6Mo_7O_{24}.4H_2O$ in 500 mL distilled water) and finally 30 mL 0.1 M ascorbic acid (by dissolving 1.76 g of the ascorbic acid in 100 mL, which is stable for about a week). The mixed reagent is stable for 8 hours only.

For a 50 mL of the sample, 8 mL of mixed reagent was required followed by 1 drop of phenolphthalein indicator. After mixing thoroughly, the sample was measured after 10 minutes but no longer than 30 minutes, using spectrophotometer at a wavelength of 880 nm. The calibration curve was obtained by analyzing blank as a reference and different standard solutions as KH_2PO_4 in deionized water [Refer to Appendix C].

3.3.8 Particle Size Distribution

The particle size distribution for the suspended solid samples was determined using the Laser Scattering analyzer (HORIBA, LA- 950V2) as shown in the Figure 3-8. This instrument has the ability to measure the particle size of dry or wet samples within a

range of 0.01 μm – 3000 μm. Triplicate measurement for each sample was done and the distribution of the particle size was generated using Microsoft Office EXCEL by plotting the accumulated percentage finer to the particle diameter on a semi log scale.

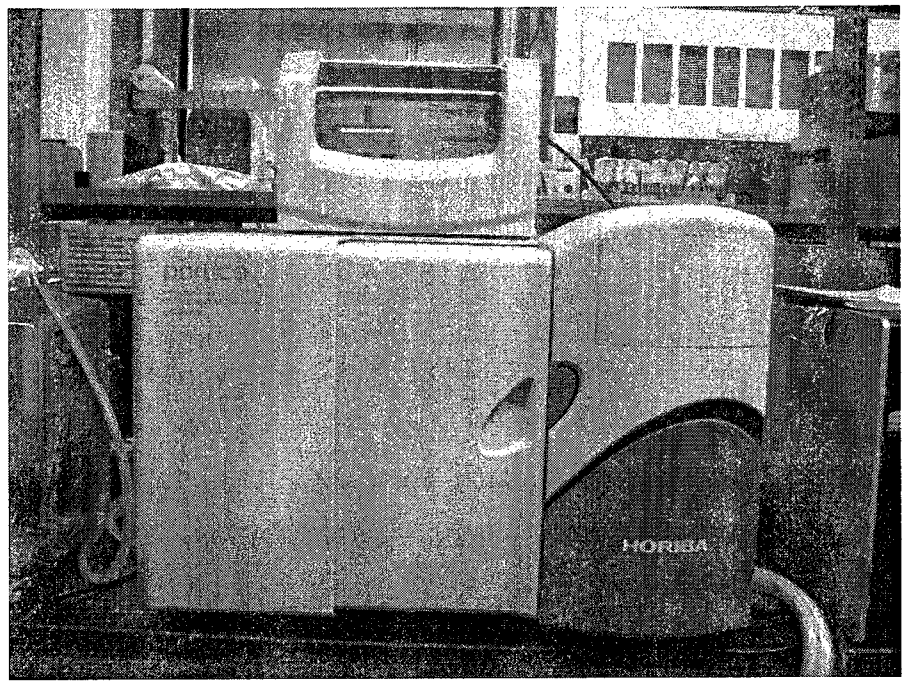


Figure 3-8 Particle Size Distribution Analyzer (HORIBA LA 950-V2)

3.3.9 Coefficient of Permeability

Permeability is considered as one of the important soil properties in designing any soil structure. The coefficient of permeability (k) is the rate of flow under laminar flow conditions through a unit cross sectional area of a porous material under unit hydraulic gradient (Koerner, 2005). In this study, a nonwoven filter was used as a porous medium and the coefficient of permeability was measured to calculate the filter ability in removing SS. Some of the factors that affect permeability of the filter include particle size distribution and pore size of the filter. In order to understand the water filtration,

Darcy developed a law that explains the correlation between water flow rate and porous media (LaGrega et al., 2001). Equation 3-2 represents Darcy's law.

$$Q = k \times i \times A \tag{3-2}$$

Where,

Q = flow rate [m^3/s]

i = Hydraulic gradient (unitless)

A= cross sectional area in which the flow passes through [m^2]

k = the coefficient of permeability [m/s]

The *hydraulic gradient i* is the defined as the proportional relationship between the hydraulic head and the thickness of the filter, expressed as $\frac{dh}{dl}$

Where,

h = the hydraulic head which is the amount of water above the filter [m]

l= thickness of the filter [m]

The filter thickness is considered in coefficient of permeability and is known as permittivity since most of the geotextiles are thick and compressible (Koerner, 2005) Permittivity (Ψ) (sec^{-1}) is expressed as:

$$\Psi = \frac{k}{t} \tag{3-3}$$

Where,

k = coefficient of permeability (m/s)

t = thickness (m)

The constant head permeability test (ASTM D 2434) method was used to measure all the parameters.

CHAPTER FOUR

RESULTS AND DISCUSSION

As outlined earlier, various pollutants are discharged into surface waters leading to surface water quality impairment. Although various measures are in action to control the discharge of these pollutants, the water body is still at risk because of the internal variations, which can release SS into the water. This leads to serious consequences for aquatic ecosystems. The main objective of this study was to remove SS from the lake water using filtration in order to reduce the problems associated with SS loading in water bodies.

The in-situ filtration unit was set up at Lake Caron and the filtration tests were performed from the month of August 2009 until the lake was frozen in the middle of November 2009. Prior to setting up of the filtration unit, bi-weekly samples were collected from all the seven stations to monitor the levels of suspended solids and phosphorus concentrations. No high productivity in aquatic plant growth was observed until mid July due to the cooler temperature. Gradually, the water temperature increased to 20°C, resulting in high concentrations of both suspended solids and nutrients levels. Once the filtration tests started at station 6, samples from other stations were analyzed on a monthly basis to monitor lake water quality.

4.1 Lake characterization throughout the months

Figures 4-1 to 4-4 shows the variations in water quality parameters, such as suspended solids, total phosphorus, chemical oxygen demand (COD) and total nitrogen. Suspended solids concentrations were high in the month of August and this might have been caused because of the rainfall that occurred frequently in the previous month resulting in surface runoff and transport of organic matter from land to water [Refer to Appendix – D]. The concentration almost remained same during the month of October and this is because of the decomposition of the algae plants that might have contributed huge amount of debris to the lake water. Green particles in suspension were seen throughout the lake.

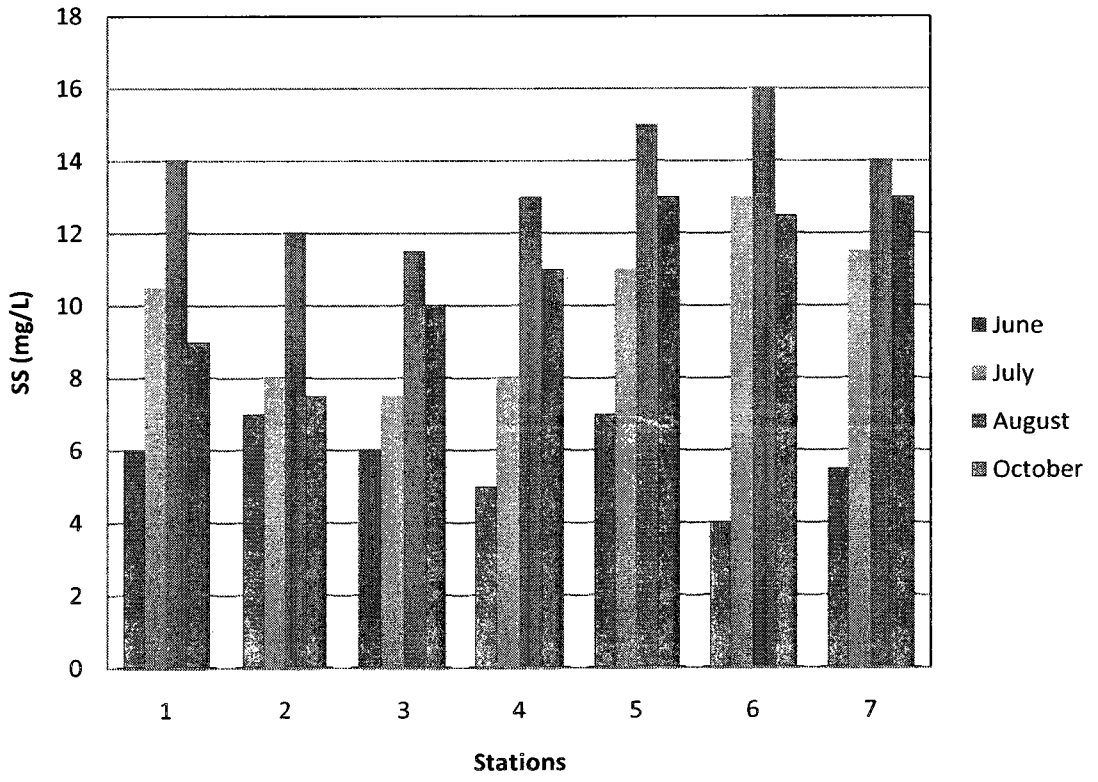


Figure 4-1 Changes in suspended solids concentrations at different stations

As the water temperature increased, gradual increase in phosphorus levels was also observed. As seen in Figure 4-2, the highest concentrations were noticed during the month of August and this is due to runoff that washes away organic matter such as leaves, twigs, grass, and other debris. This is one of the important sources of nutrient loading as the decomposition of organic matter releases nutrients into the water. However, phosphorus concentrations were low during the month of October because of the low productivity and seasonal changes. The other two important quality indicators that were measured are COD and TN. COD concentrations increased with the increase in the organic matter in the water. No significant changes were observed in the total nitrogen concentration as this nutrient becomes a major part of productivity only when there is no phosphorus available for plant growth

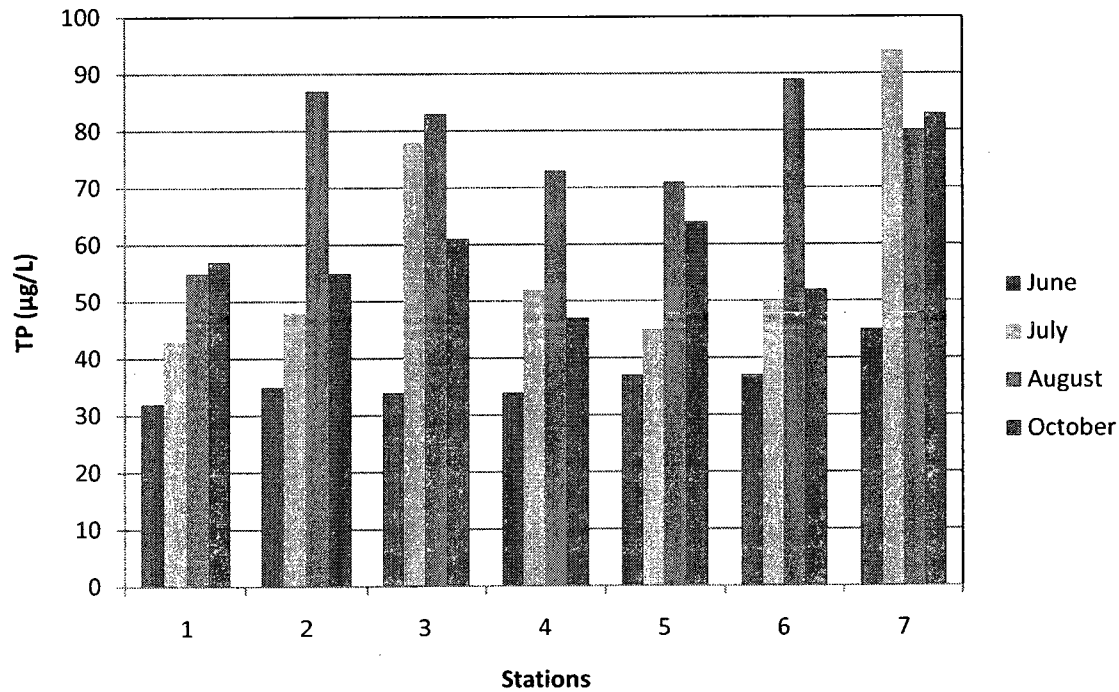
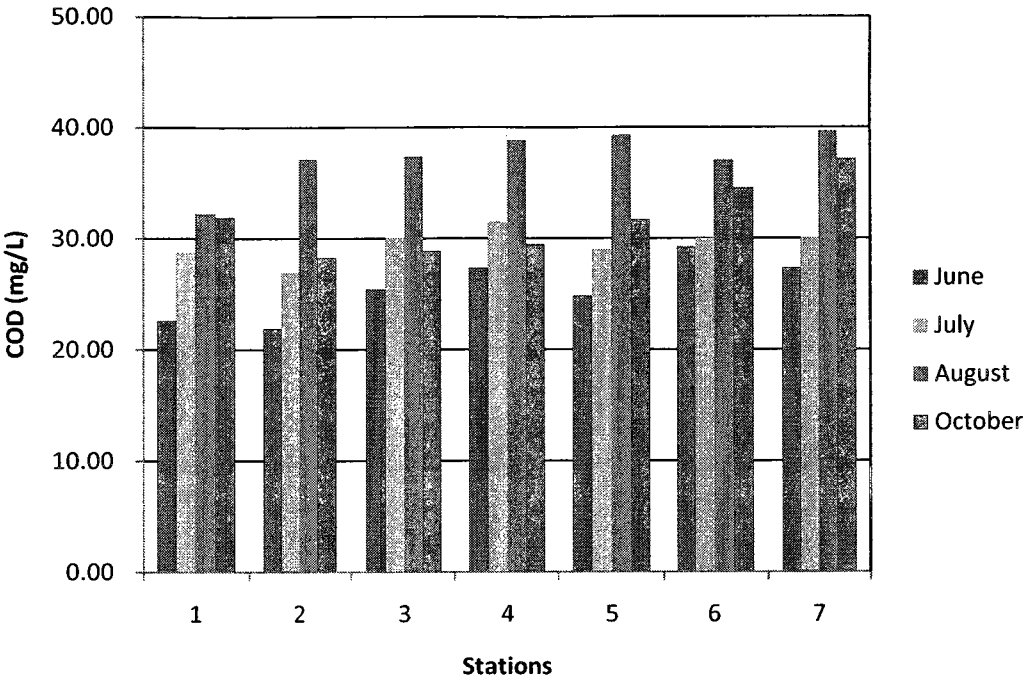


Figure 4-2 Changes in TP concentrations at different stations



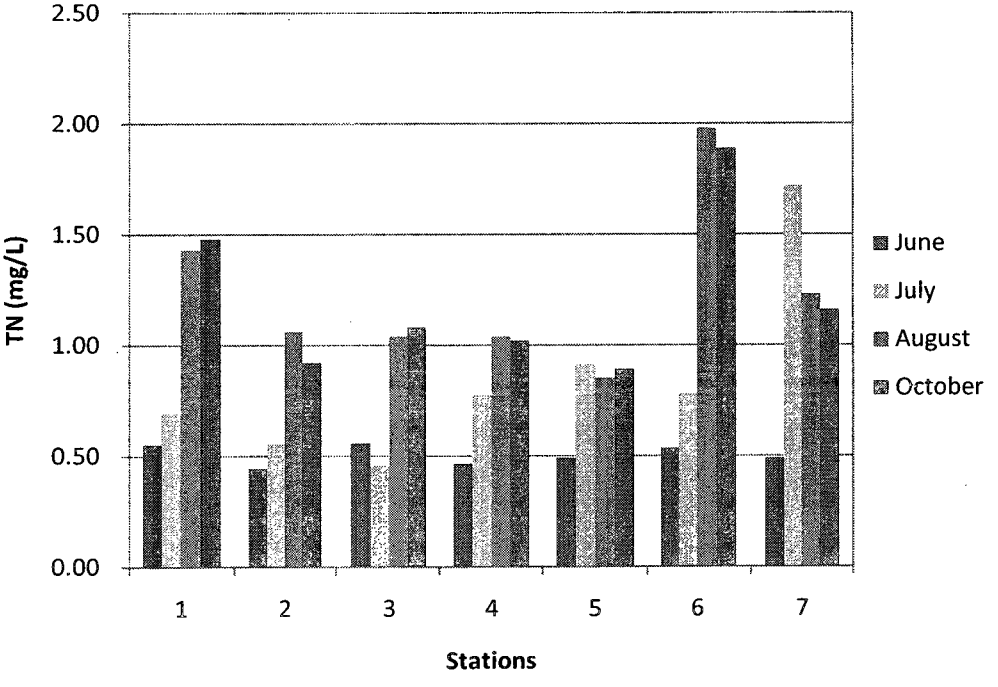


Figure 4-3 Changes in COD and TN concentrations at different stations

4.2 Filtration tests

The samples collected before and after filtration were analyzed for both suspended solids and phosphorus concentrations. Discussion has been made independently for each contaminant with respect to each filter. Each measurement was done in duplicate and in some cases triplicate and the average was reported. The error was calculated for all measured data and average error using the standard error was reported in the graphs. The standard errors vary according to the number of experimental replications. Triplicate measurements tend to result in smaller errors as compared to duplicate measurements. The error margin was between 5.3% and 11.5%. Also, it is important to consider the factor of seasonal changes and other unknown reactions that might have occurred resulting in the sporadic changes of the nature of pollutants. According to Michaud (1991), how and why they change is a very complex field of study. Based on the average values of before and after filtration, over the duration of experiment, the percentage removal was calculated for all different filters with respect to different parameters. Equation (4-1) was used to calculate the percentage removal.

$$\text{Removal efficiency (\%)} = \frac{\text{Average (Before filtration)} - \text{Average (After filtration)}}{\text{Average (Before filtration)}} \times 100 \quad \ldots (4\text{-}1)$$

4.2.1 Suspended solids

The removal efficiency of the filtration unit depends on the particle size of the solids that need to be removed. The analysis of the suspended solids from Lake Caron was performed using the HORIBA LA- 950V2 Laser scattering analyzer and the graph was generated using Excel. The range of particle size detectable by this instrument is between 0.01 μm to 3000 μm. The particle distribution curve is obtained by plotting the percent of

total material less than certain sizes. These sizes are determined by couple of laser emissions, and classified according to the wave length of the laser provided by the instrument. The detailed analysis report was generated by the instrument describing the relation between the percentages of particles under size (percent finer calculated from the initial sample amount) versus particle diameter [Refer to Appendix E].

Figure 4-4 represents the particle size distribution for the sample taken from station 6 (station where instrument was set up) during the month of August 2009. Two samples were collected in an interval of two weeks to see the changes in the particle size distribution. All the samples analyzed had a very similar particle size distribution and hence the below figure represents the distribution for a sample collected on 26th of August. According to the results obtained, the sample mainly consisted of particles in the size range of silt and sand in all the samples.

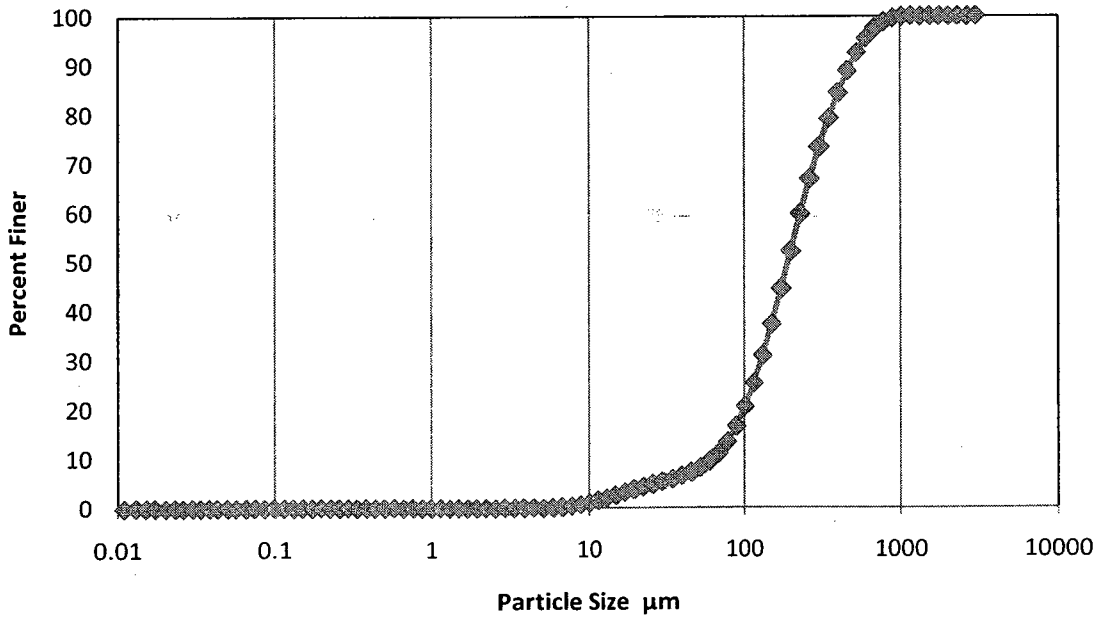


Figure 4-4 Particle size distribution from Station 6 sample

4.2.1.1 Removal of SS using LP-12 filters

According to the preliminary experiments that were carried out in the year 2008, LP-12 nonwoven filter with AOS of 150μm and thickness of 0.2cm was acceptable for removing SS. Hence, the same filter was used for the in-situ filtration tests which started during the month of August 2009. To keep the filtration running, filters were changed once it reached the clogging condition. Therefore every time a new filter was changed, it was referred to as Filters No 1, 2 and 3.

Figure 4-5 illustrates the suspended solid reduction obtained for filter 1. As pumping began, a thin green layer of algae was formed on the filter media. After a couple of hours, a loss in the hydraulic head was noted along with the formation of the thin grey layer of solids on the filter media. The concentration of the SS reduced in the filtrate collected until day3. As seen in the figure, there is a sudden spike in the concentration of SS in both before and after filtration samples. This might have been caused by the resuspension that occurred within the uncovered filter column because of the heavy rainfall which disturbed the particles settled on the filter media. This released the particles through the filter, which increased the filtrate concentration.

On the other hand, it was noticed that filamentous algae had started growing on the filter media, which resulted in creating a muddy zone within the filter column. The fluctuation in the concentration continued slightly until the filter clogged on day 13th. Some of the possible reasons that could have caused fluctuations are experimental variations, resuspension within the system, biodegradation and reformation of bigger particles and to some extent breaking of smaller particles which passes through the filter. The

concentration in the filtrate remained 2 mg/L or less which is acceptable for Canadian guidelines for SS concentration in surface water. The removal rate of SS obtained from filter No 1 was 71.5%, which is a fair removal considering the natural factors that decreased filtration process.

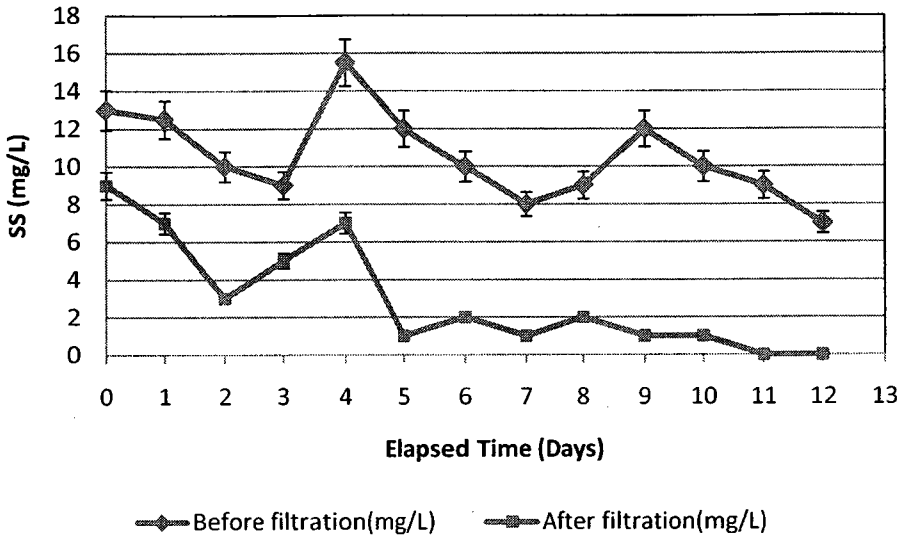


Figure 4-5 Reduction trend in SS concentration from filter 1

To overcome the effects caused by the growth of algae and seasonal changes on the filter medium, the filter column was covered with a tarpaulin before continuing the filtration tests with the filter no.2. With the use of a tarpaulin to cover, algae growth within the column was reduced as the sunlight necessary for the growth was blocked.

During the filtration process with filters 2 and 3, the same trend was observed in both the cases for removing suspended solids. No substantial removal was seen until the filter cake was formed. This is because, at the initial stages of filtration, most of the particles less than the AOS of the filter passed through the filter. Since this filter is thin, it has a lower solids retention capacity. After day 4, it was observed that the remaining particles

which were deposited around the pores started to clog the pores thereby trapping the smaller particles. The newly formed filter on the surface of the medium led to high removal rate of SS from day 5 and remained constant until the filter clogged completely. Although the filtrate quality was good towards the end, the removal rate of SS obtained was only 80%. Figure 4-6 and 4-7 illustrates the SS reduction by filters 2 and 3.

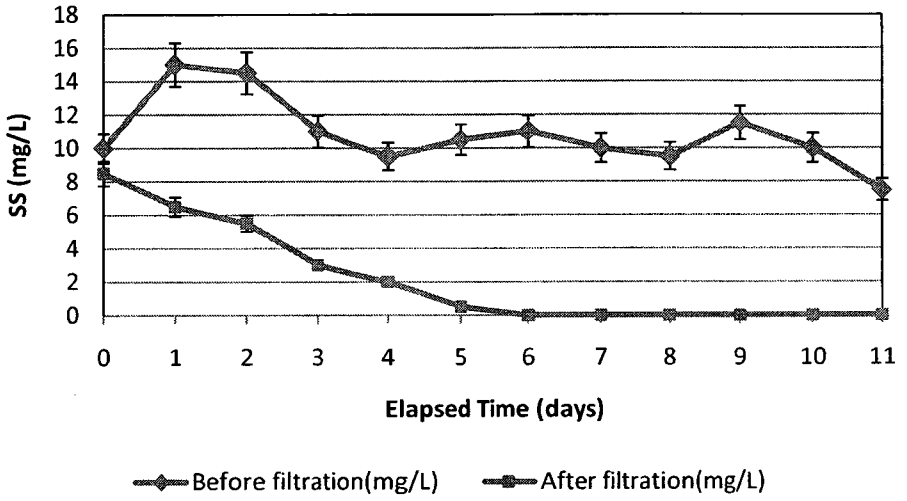


Figure 4-6 Reduction trend in SS concentration from filter 2

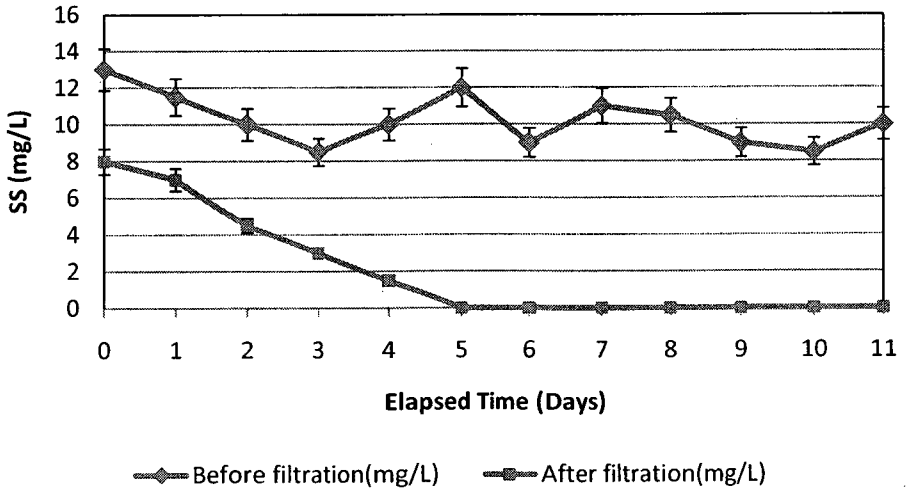


Figure 4-7 Reduction trend in SS concentration from filter 3

4.2.1.2 Removal using GTX-300

The GTX series of nonwoven filters was obtained from Checkmate Geosynthetics with different AOS and thicknesses. GTX-300 with AOS of 125 μm and thickness of 0.36 cm is referred to as Filter No. 4 throughout the discussion. The SS removal rate was almost 70% within the first three days of filtration. This was possible because of the ability of the filter to trap the smaller particles at the very beginning of the filtration on top of the filter cake formed by larger particles. This filter has a larger thickness as compared to the rest of the filters which resulted in better adsorption of finer particles at the surface as well as within the layer of the medium. After 5 days of continuous filtration, a removal rate of 82% was achieved. But due to the lower AOS, the filter clogged within a week thereby rendering it unusable for long term filtration. Figure 4-8 explains the removal trend obtained for filter 4.

Although the early clogging condition was understood with respect to 2 layers of filter 4, five layers of same material was used to check if there would be any significant improvement in the filtration efficiency in terms of phosphorus removal. As expected, the filter clogged within five days of starting the experiment with 87% of SS removal. This is clearly seen in Figure 4-9. Even though this filter could reduce the amount of SS in a short period of time, using this filter would not be practical due to frequent replacement. Instead of using multiple layers of same material, filter layer with a larger pore size could be placed before the smaller pore size.

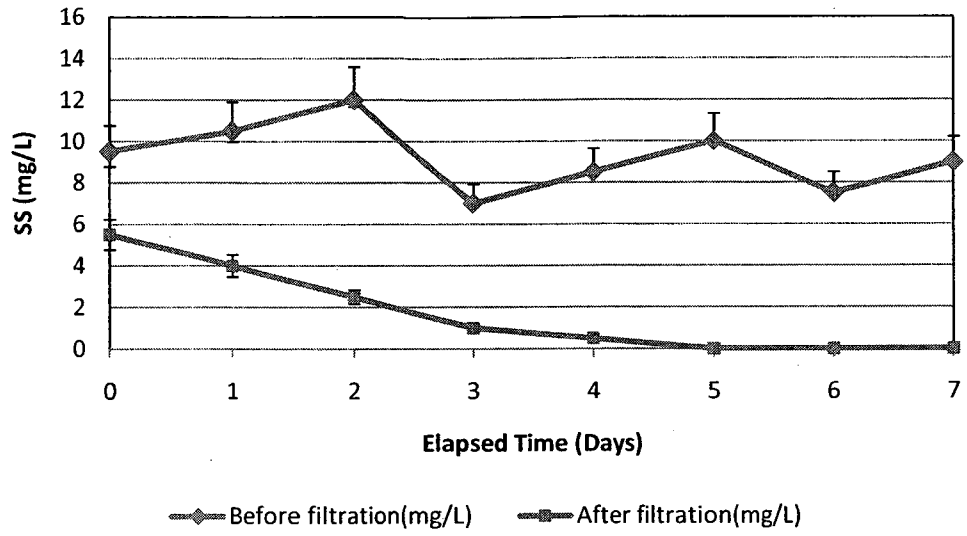


Figure 4-8 Reduction trend in SS concentration from filter 4

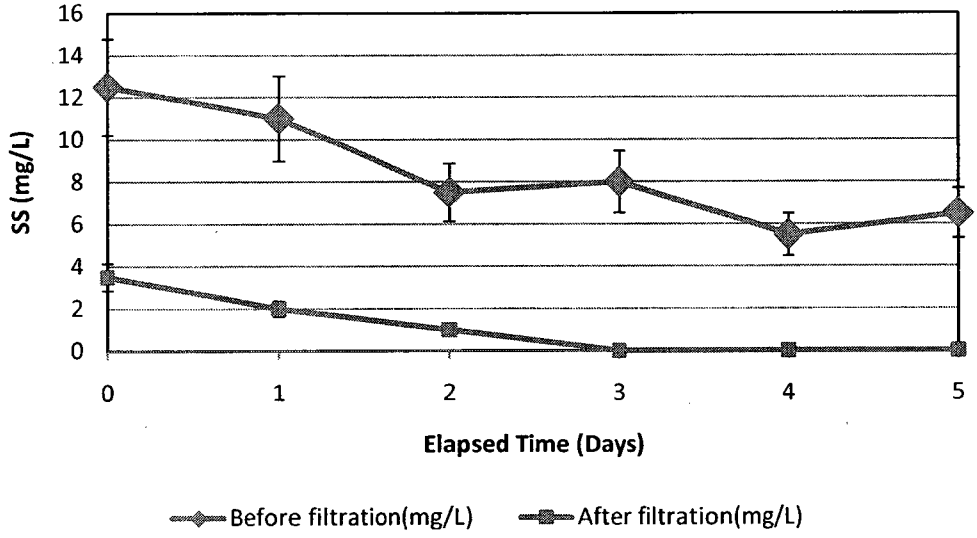


Figure 4-9 Reduction trend in SS concentration from filter 5 with 5 layers

4.2.1.3 Removal using GTX-200

GTX- 200 has the same AOS of 125μm but with a smaller thickness of 0.24 cm. This filter followed the same trend as filter 4 for removing SS but with lesser removal rate

because of its lower retention capacity of solids. As seen in Figure 4-10, after 5 days of filtration, removal of SS was achieved because of the formation of the filter cake. This series of GTX filter showed the least performance of 77% with respect to SS removal.

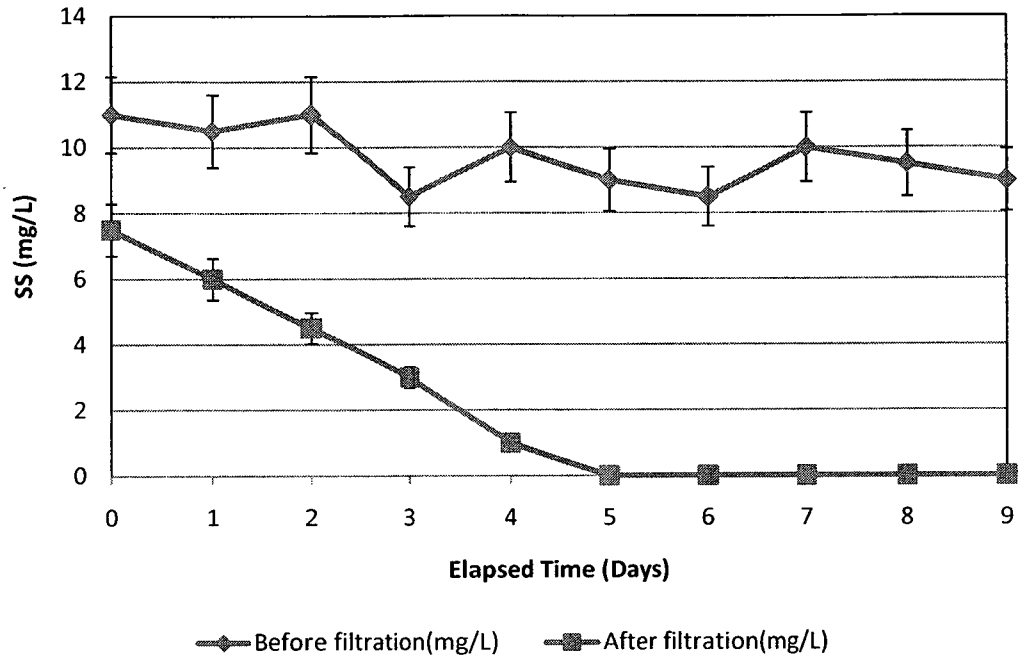


Figure 4-10 Reduction trend in SS concentration from filter 6

4.2.1.4 Removal using GTX-250

The GTX- 250 geotextile with AOS of 150 μm and thickness of 0.3cm performed well with respect to all other filters in terms of SS removal. The initial concentration of solids was a little higher when compared to the rest of the cases due to the heavy storm that occurred prior to the filtration tests. By visual observation it was seen that the filter cake was formed by day 4, which led to substantial removal of solids. Filter thickness might be one of the reasons for good solids retention capacity. It seems from Figure 4-11 that filtration tests could have been stopped after day 10 since the removal capacity remained

constant from day 4. But the filtration was continued to study the effect on phosphorus removal. However, the filtration test was stopped due to extreme weather conditions. This filter removed 91% of SS without clogging even after 13 days.

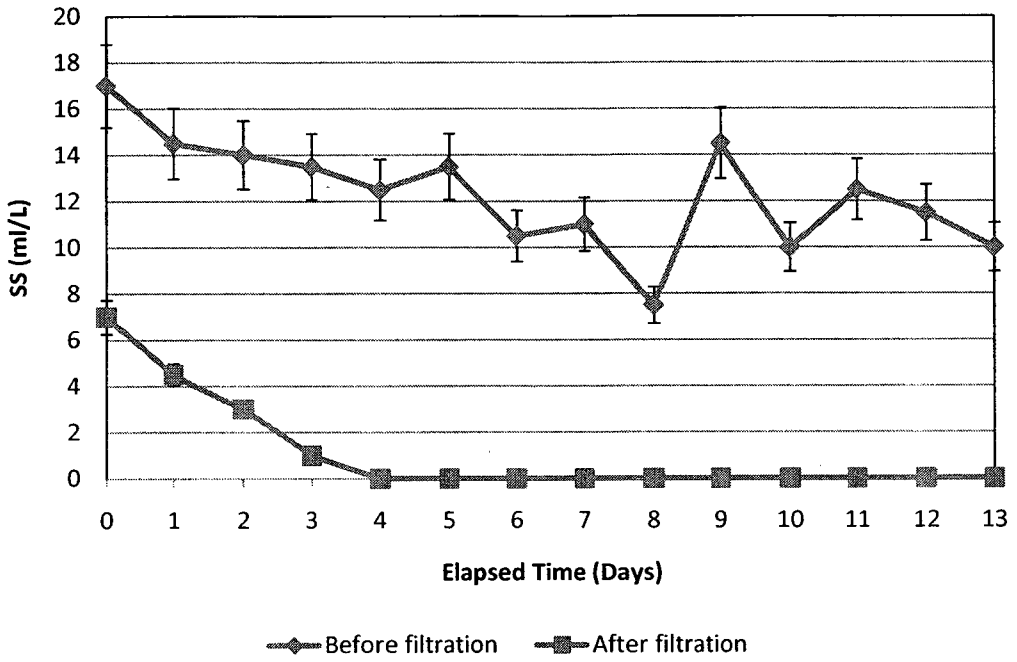


Figure 4-11 Reduction trend in SS concentration from filter 7

4.2.2 Phosphorus

When the filtration tests started, the value of the total phosphorus in the water corresponded to the eutrophic state from the Canadian guidelines for TP for lakes and rivers. The reduction of phosphorus through filtration tests was dependent on the type of the filter used, solids concentration and SS removal efficiency. The removal rate obtained for phosphorus was different for each filter used.

The phosphorus concentration in the lake water varied throughout the filtration tests. Hence the values obtained from before filtration samples fluctuated every day. Some of the possible reasons that would have caused depend on environmental conditions, phosphorus cycle in the water and internal loading of P by decomposition of algal blooms that sank to the bottom water which caused regeneration of P from sediments.

4.2.2.1 Removal using LP-12 filters

During the entire filtration process, it was observed that with the decrease in the SS concentration the levels of phosphorus also reduced. This was a common trend observed in all the cases. As explained in the case of SS removal for filter 1, the environmental factors affected the phosphorus removal as well and this can be seen in Figure 4-12. In the case of SRP (Figure 4-13), on the fourth and fifth days of filtration process, the filtrate concentration was more as compared to the sample taken before filtration. This might be because of the resuspension of the particles which break down the algal cells that was trapped on the filter and releasing phosphorus through the filter. There was no significant removal of phosphorus until the SS concentration was reduced to 2 mg/L or less.

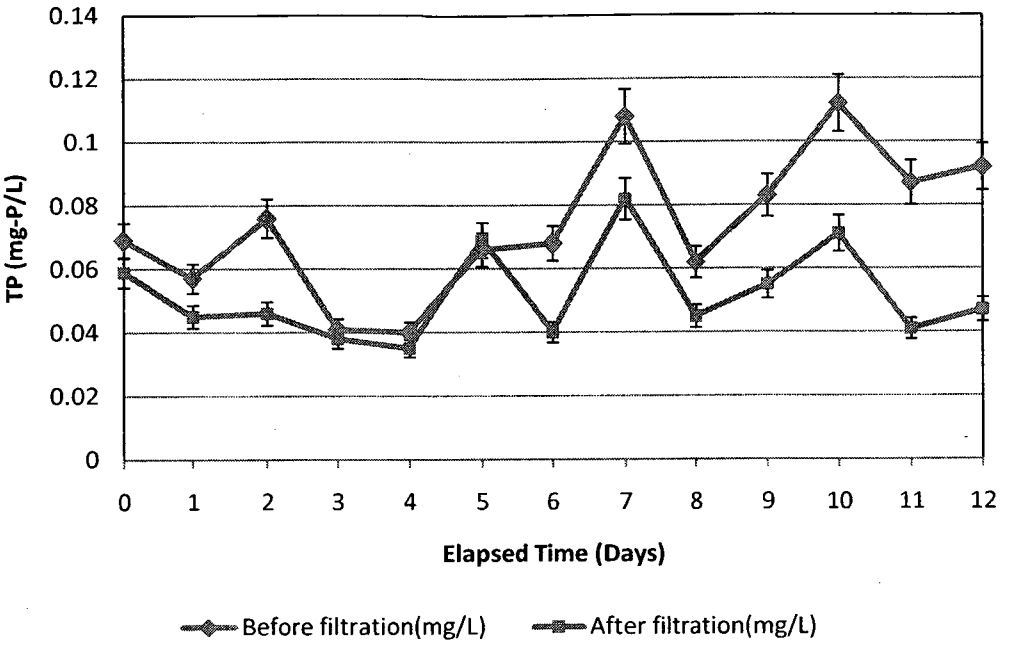


Figure 4-12 Reduction trend of TP from filter 1

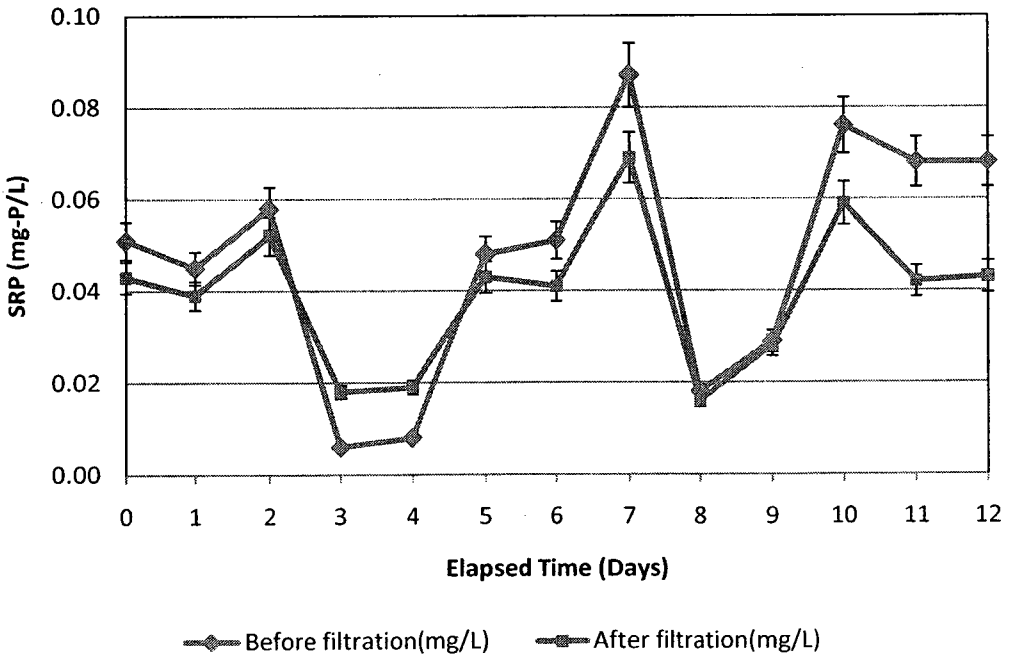


Figure 4-13 Reduction trend of SRP from filter 1

The total phosphorus removal in the case of filters 2 and 3 was achieved only after the fifth day of the filtration. This may be because the larger particles which were initially retained could remove only a small amount of phosphorus. On the other hand, with the continuous filtration, and the clogging of the pores with the larger particles, smaller particles with higher concentrations of phosphorus were filtered reducing the concentration to 0.04 mg-P/L or less. Figure 4-14 shows the reduction of TP from filter 2.

A bio-film that was formed on the surface of the filter reduced the SRP concentration in the filtrate with removal rate of 37% and 35% for filter 2 and 3 respectively. Such a small removal rate was obtained due to the thinness of the filter, whose retention capacity was changing as filtration progressed. Figures 4-16 and 4-17 show the reduction rate of SRP from filters 2 and 3 respectively.

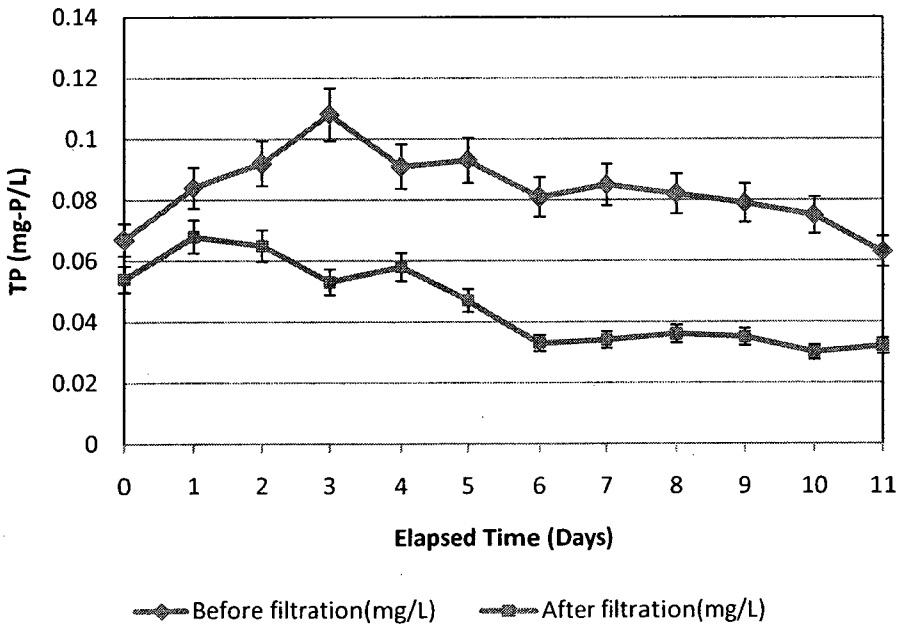


Figure 4-14 Reduction trend of TP from filter 2

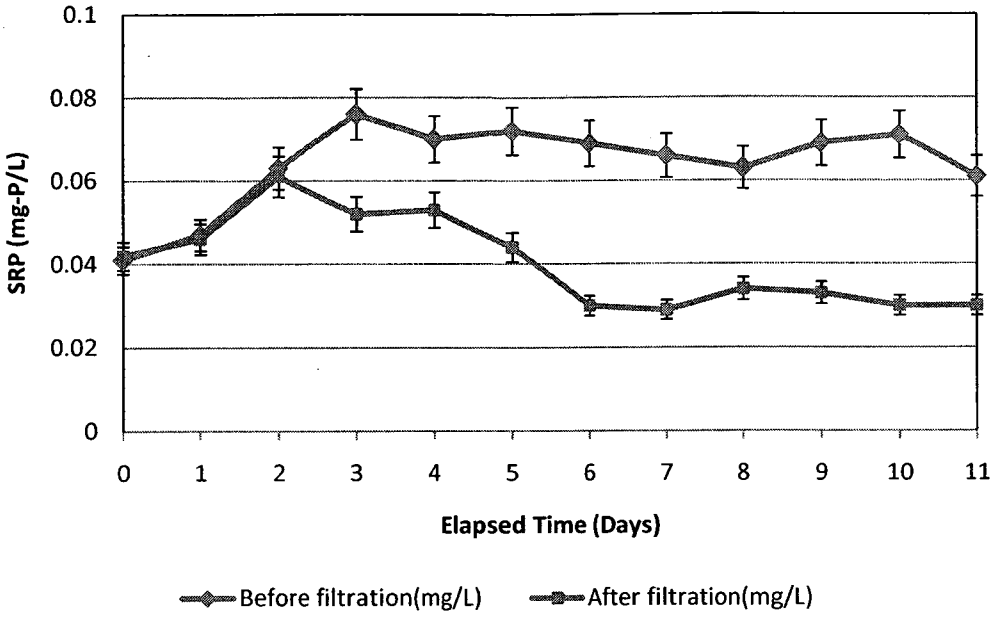


Figure 4-15 Reduction trend of SRP from filter 2

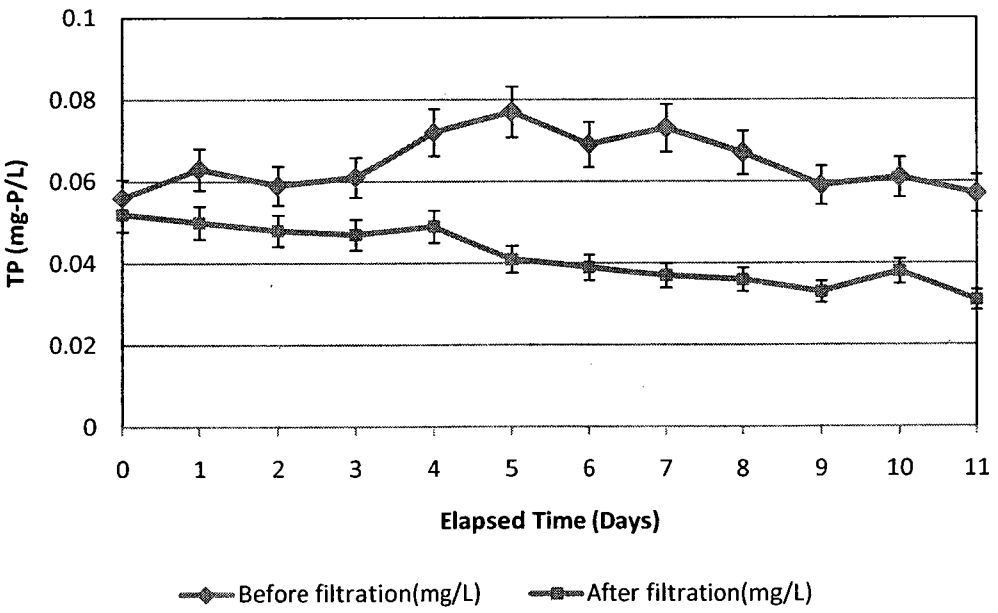


Figure 4-16 Reduction trend of TP from filter 3

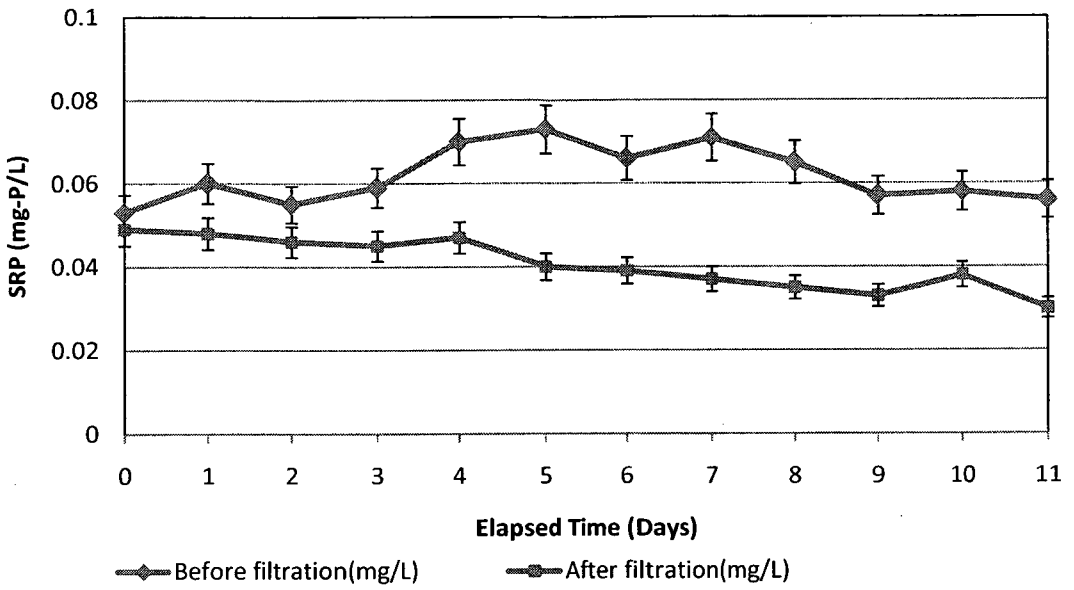


Figure 4-17 Reduction trend of SRP from filter 3

4.2.2.2 Removal using the GTX-Series geotextile filter

The GTX series of filters showed considerable removal of phosphorus by filtration. Although initially it seems that filters 4 and 5 remove phosphorus effectively (Figures 4-18 and 4-20), this type of filters was not suitable for long term filtration due to the clogging that occurred within a week after starting the filtration. If sufficient permeability was maintained by using a larger pore size before the smaller pore size filter, better removal rate of phosphorus could have been achieved. The concentration of SRP in both the filters reduced along with the decrease in the TP concentration. This may be because of the smaller opening size of the filter that would retain smaller particles with a higher concentration of phosphorus. Figures 4-19 and 4-21 show the reduction trend in the SRP concentration by filters 4 and 5 respectively.

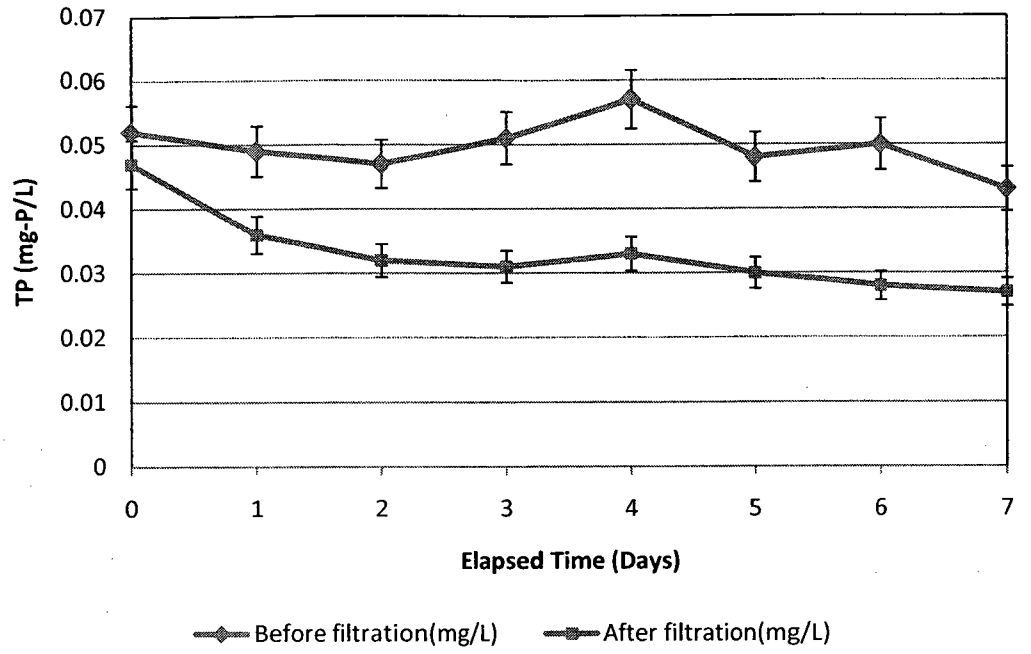


Figure 4-18 Reduction trend of TP from filter 4

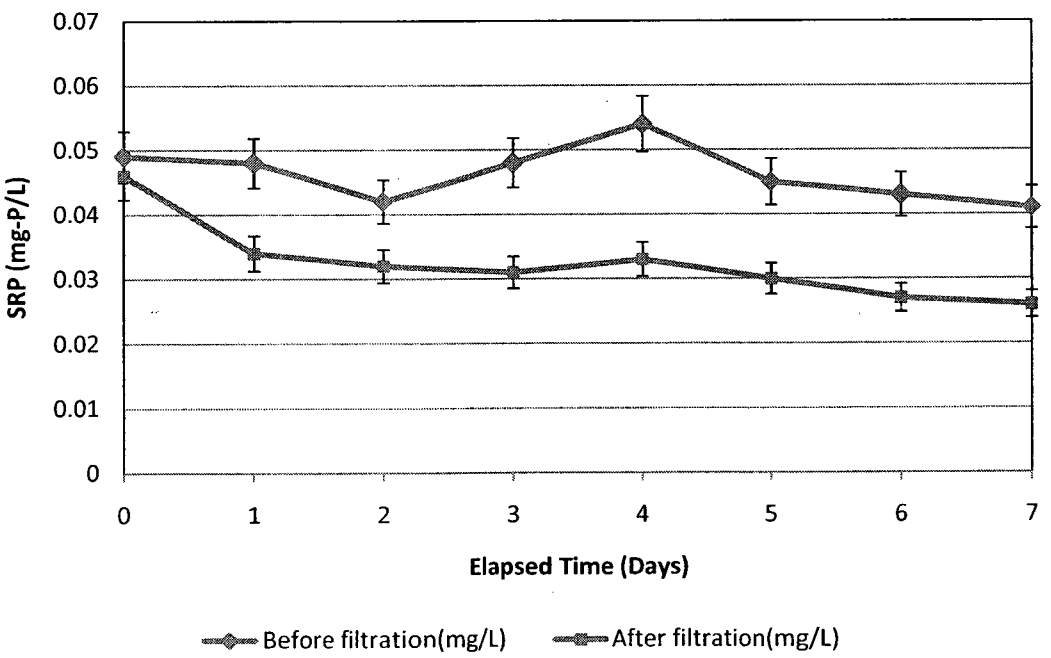


Figure 4-19 Reduction trend of SRP from filter 4

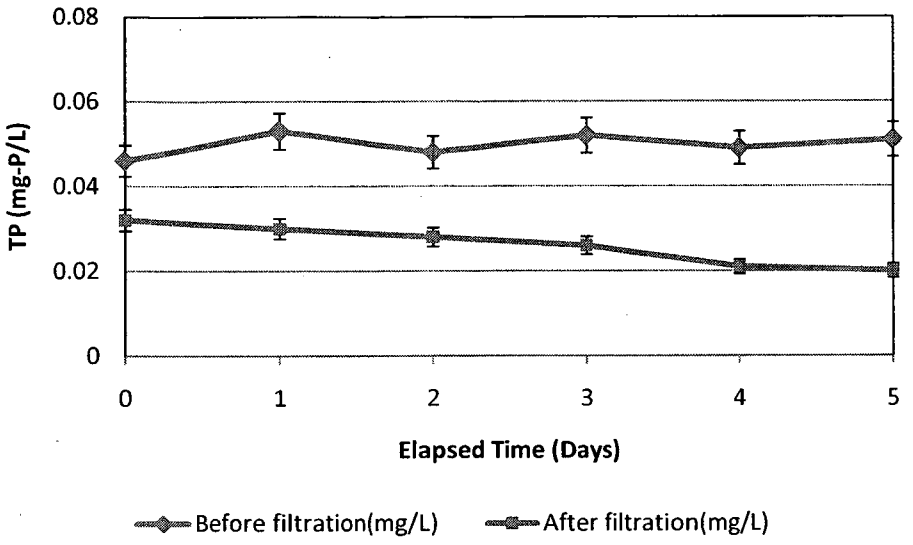


Figure 4-20 Reduction trend of TP from filter 5

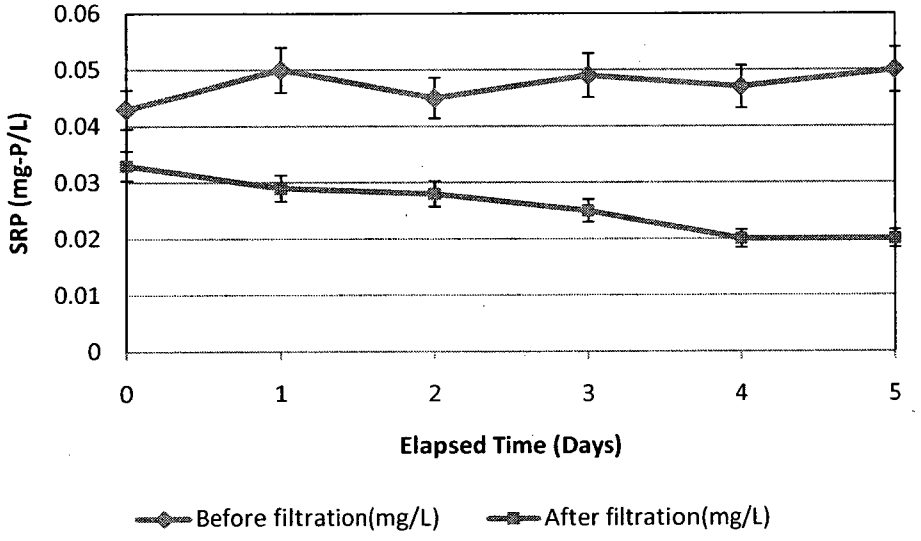


Figure 4-21 Reduction trend of SRP from filter 5

Filter 6 showed the lowest performance in removing both SS and phosphorus as compared to the other GTX series. The filter's small thickness with a lower solids retention capacity, led to the least P removal rate of 30% only. Since the filter layer

formed was very thin, no substantial removal of SRP was observed. Figures 4-22 and 4-23 show the changes in the concentration of phosphorus as filtration progressed.

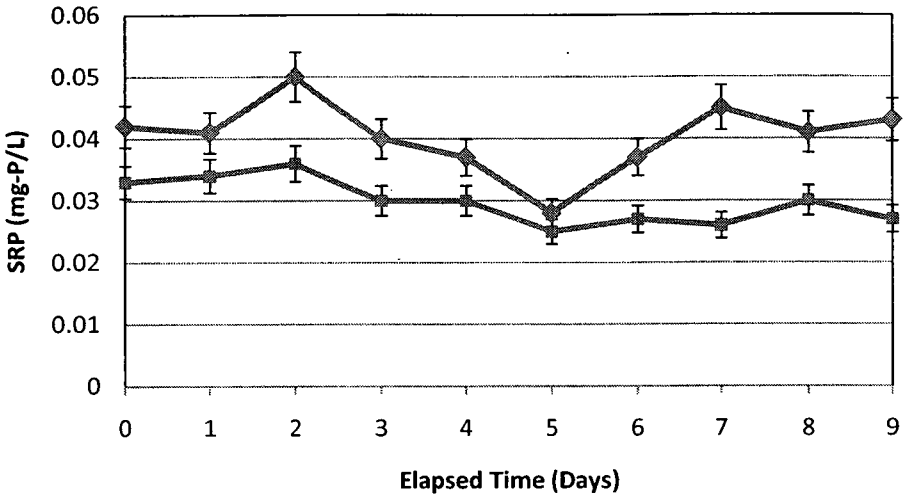


Figure 4-22 Reduction trend of TP from filter 6

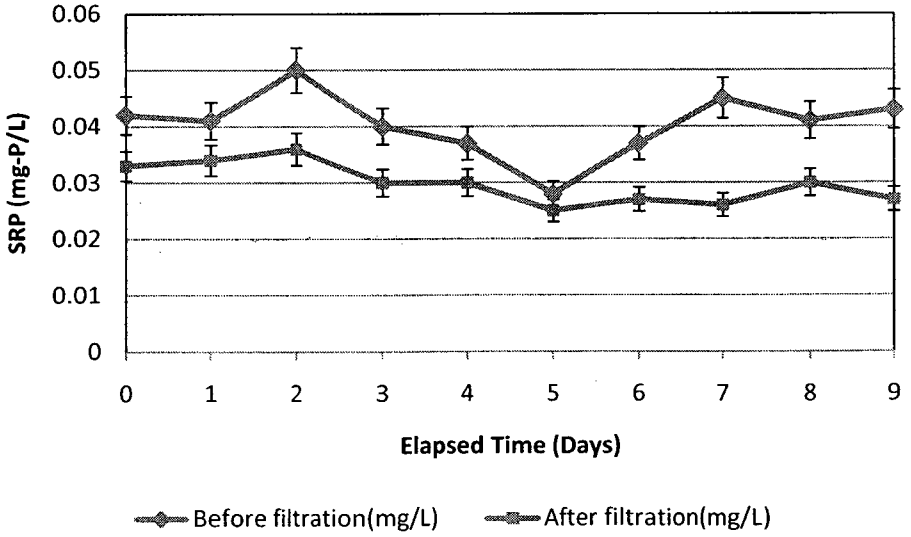


Figure 4-23 Reduction trend of SRP from filter 6

Figures 4-24 and 4-25 show the decrease in the TP and SRP concentration by the filtration using filter 7. In the case of TP, the concentration reduced from 0.08 mg-P/L to 0.02 mg-P/L or less corresponding to the mesotrophic state of the Canadian standards for TP triggers values in lakes and rivers. This is due to the filter cake that was formed on the filter which led to the good adsorption of phosphorus. After day 6, there was a sudden increase in the filtrate concentration because of an increase in the SS load which might have released some smaller particles with a higher P concentration. Despite the higher concentration, the permeability of filter did not decrease significantly, indicating that the filter did not clog and resulted in good removal efficiency of both SS and P. This may be because of the good AOS and thickness of the filter. In addition, it was observed that the clogged filter enhanced removal of SRP by biodegradation and adsorption of SS. The concentration reduced from 0.07 mg-P/L to 0.01 mg-P/L as the filtration progressed. A removal rate of 63% and 60% was obtained for TP and SRP respectively.

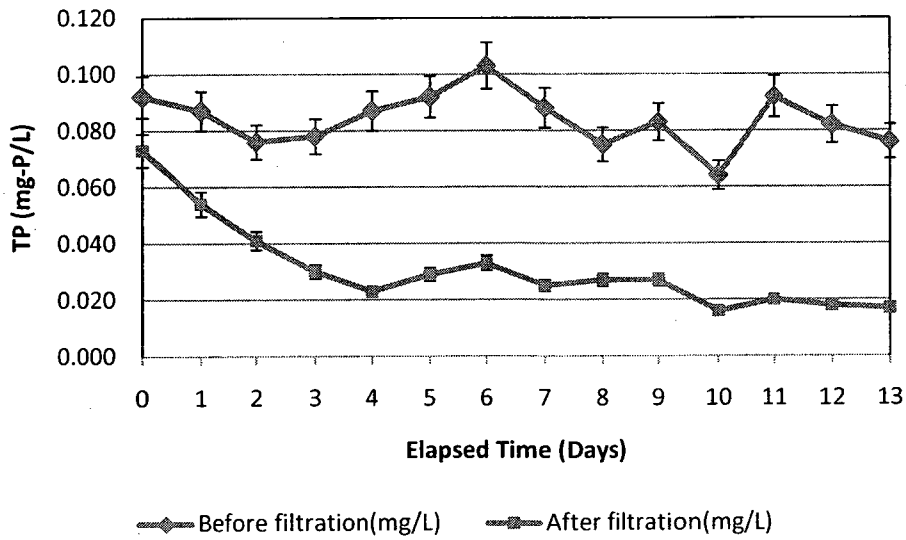


Figure 4-24 Reduction trend of TP by filter 7

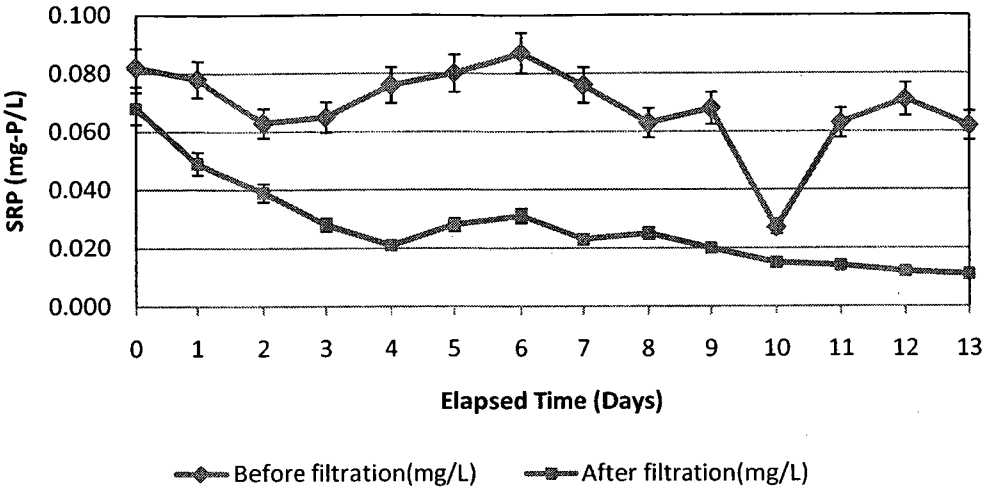


Figure 4-25 Reduction trend of SRP by filter 7

Once the filtration test was done, the P content on the filter was calculated as mentioned in Chapter Three. For continuous filtration of 14 days, the amount of P that was retained on the filter was found to be 6.25 mg/kg. Along with the phosphorus content trapped in the SS, other materials like debris and filamentous algae that were pumped might have contributed to additional phosphorus on the filter.

Based on the average values before and after filtration, the percentage removal was calculated for all different filters with respect to different parameters and is as shown in Table 4-1. Filter 7 (GTX-250) was effective in removing both SS and phosphorus as compared to the rest of the filters.

In addition to removal efficiency, the removal rate for both SS and phosphorus was calculated. This is because it has been noted that it is more accurate to account for the removal amount than that from the change in water quality (Fukue et al., 2008). Since

filter 7 (GTX-250) has shown good removal efficiency, the overall amount of contaminants removed from this filter was alone considered.

Table 4-1 Removal efficiency obtained from of each filter

Filter No		REMOVAL EFFICIENCY (%)		
		SS	TP	SRP
LP -12	1	71.5	30.0	16.5
	2	80.0	45.5	37.0
	3	80.4	35.2	34.4
GTX - 300	4	81.7	33.5	30.0
	5	87.2	47.5	45.1
GTX - 200	6	77.3	30.2	26.2
GTX-250	7	91.0	63.1	60.0

For solids, the removal rate was determined by measuring the amount of solids that was removed over the duration of the experiment. These values were then divided by the area of the filter and the time of the experiment to calculate the weight of the solids removed (g) per m^2 of filter area per second. To calculate the amount of P removed on the filter, the same steps were followed. The average values are reported. The amount of SS and TP removed by filtration was 6.365 mg/ m^2-sec and 0.0183 mg/ m^2-sec respectively. This shows the filter was effective in removing SS as well the phosphorus associated with it.

Using this technology with the above removal rates, the removal of SS and TP for the entire lake is possible when it is scaled up to a larger unit. The design extended into three

filters with geotextile area of 4 m^2 each, placed strategically as shown in Figure 4-26 can remove TP in less than eight months and SS in less than four months. The stations 3 and 7 being highly eutrophic would be the best place to set up the filtration units since, the East-West winds create a current which result in the accumulation of SS being washed off. Also, the third unit can be placed in the middle of the lake in between station 5 and station 4 to treat the less eutrophic center-east side of the lake. These calculations were based on the values shown in Table 4-2, obtained during the filtration process [Refer to Appendix – F]

Table 4-2 Removal rate for the entire lake

No. of Units	Area of one geotextile	Volume of Lake Water	Total amount of contaminants in Lake		Time required for removal	
			SS	TP	SS	TP
3	4 m^2	50200 m^3	618535 g	4213g	4 months	8 months

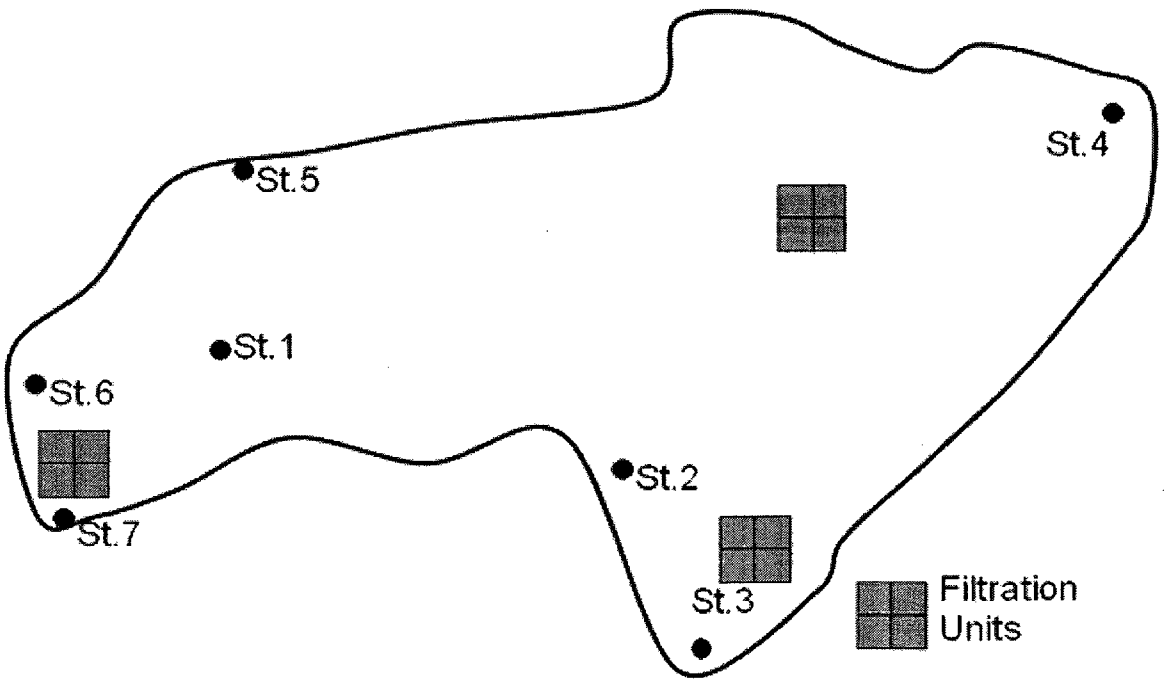


Figure 4-26 Lake Caron with filtration units

This design, if implemented during the end of April, until October, in conjunction with resuspension techniques (discussed further in Chapter 5) will not only help in improving the lake quality, but also serves as an effective technology for future individual cases associated with ponds, streams, rivers and coastal areas.

4.3 Correlation between SS and TP

In this study, it was observed that there was a strong relationship between SS removal and phosphorus reduction. This is because with the decrease in the SS concentration, the levels of phosphorus also reduced, indicating that phosphorus is adsorbed on SS (Fukue et al., 2008). This relationship can be explained better by plotting the results of SS removal and P removal in one graph and to correlate the two parameters. Figures 4-27 and 4-28 show the correlation obtained between SS removal and phosphorus removal with respect to each filter. The relationship is almost linear in all filters, but the highest correlation coefficient (R^2 = 0.907) was obtained for filter 7 indicating that as filtration progressed the total phosphorus levels also decreased with the SS removal. The removal of TP can be expressed by

$$TP = a\,SS + b \qquad (4\text{-}2)$$

Where, TP is the concentration of total phosphorus at a function of SS and a and b are constants from the below correlation graphs (Fukue et al., 2008).

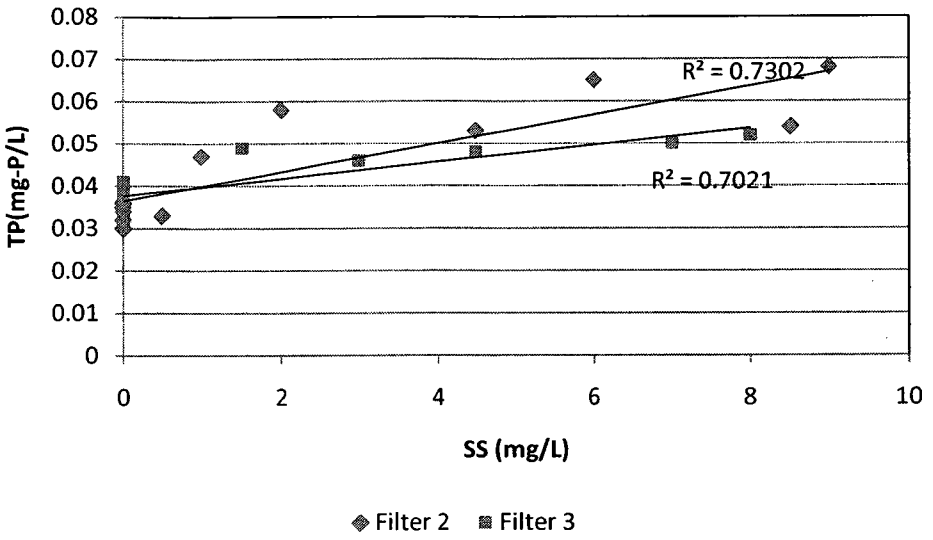


Figure 4-27 Correlation between SS removal and TP reduction in case of LP filters

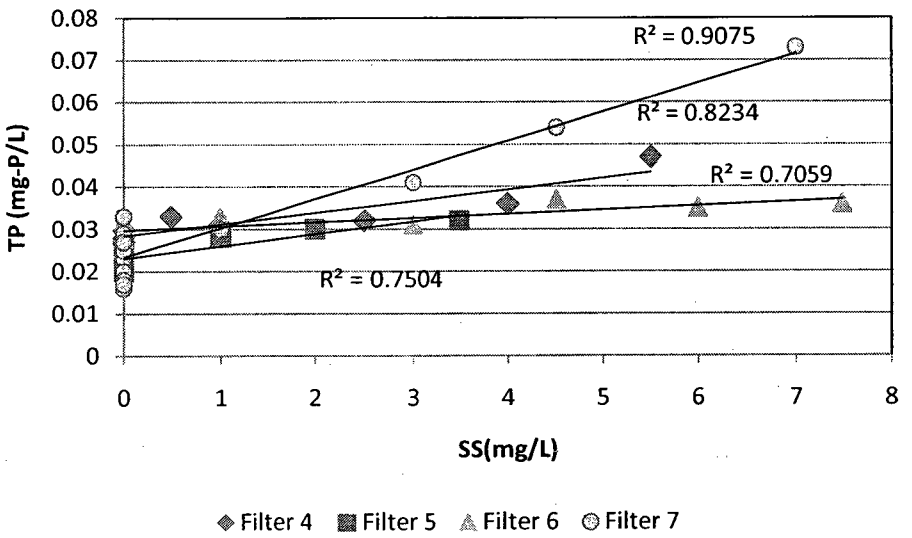


Figure 4-28 Correlation between SS removal and TP reduction in case of GTX filters

4.4 Total Nitrogen

Samples collected were analyzed for TN concentrations in order to monitor the water quality during the filtration process and to check if there was any reduction with respect

to nitrogen values through filtration. When filtration tests were started, the TN concentration in the lake corresponded to meso-eutrophic level as specified by the standards of OECD (1980) in their studies on classification of lakes and reservoirs according to the extent of nutrient enrichment. Figures 4-29 to 4-33 show the changes in the TN concentration as filtration progressed. GTX series of filters performed better compared to LP filters. However, the overall filtration efficiency of 23.7% and 19.2% was obtained in the case of filter 5 and 7 respectively. This is clearly shown in the figures below.

From previous sections, it is clear that this technology performs efficiently based on the rate of clogging, adsorption capacity of the solids and the nature of the contaminant being removed. As nitrogen in the forms of nitrate and nitrite (anionic), does not bind as negatively charged particles as phosphorus does, it is difficult to remove dissolved forms of nitrogen (Yong et al., 2007). With the removal efficiencies obtained, it seems that a small fraction of particulate nitrogen was removed. In addition, it was also observed that TN concentration in the lake almost remained stable even during the algal blooms break outs. This shows that in Lake Caron, total nitrogen was not the factor for causing eutrophication.

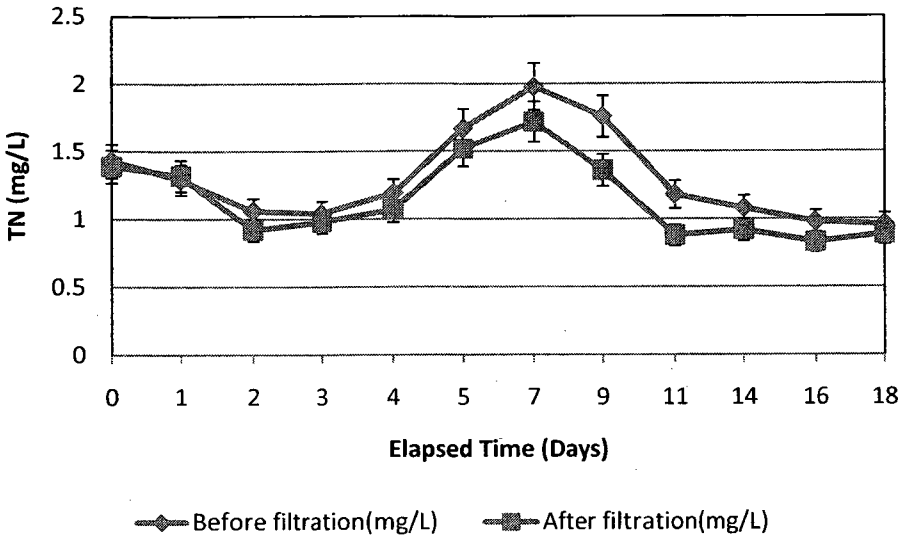


Figure 4-29 Changes in TN concentration by LP filters

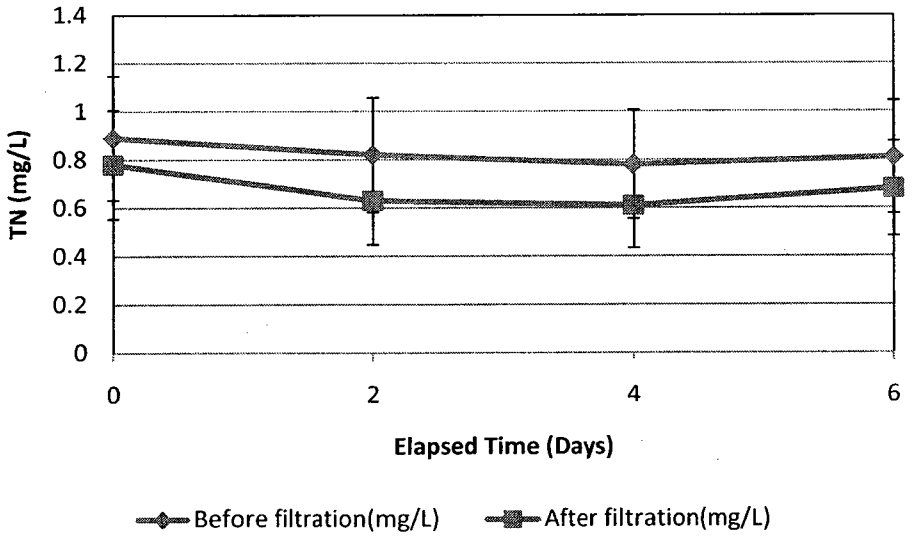


Figure 4-30 Changes in TN concentration by filter 4

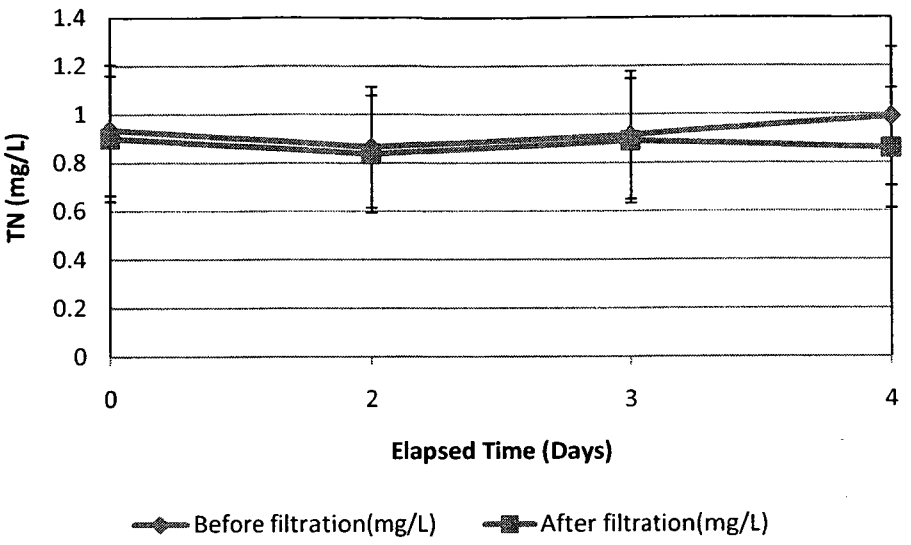


Figure 4-31 Changes in TN concentration by filter 5

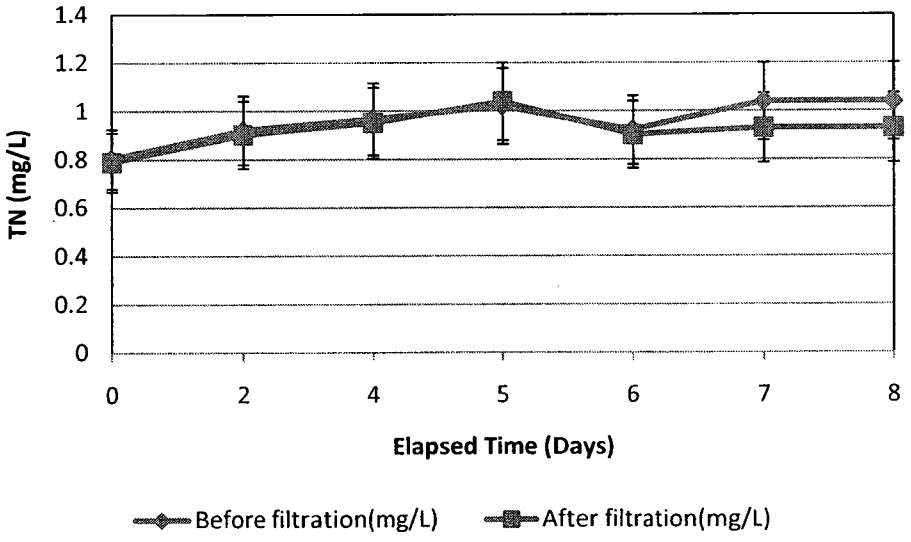


Figure 4-32 Changes in TN concentration by filter 6

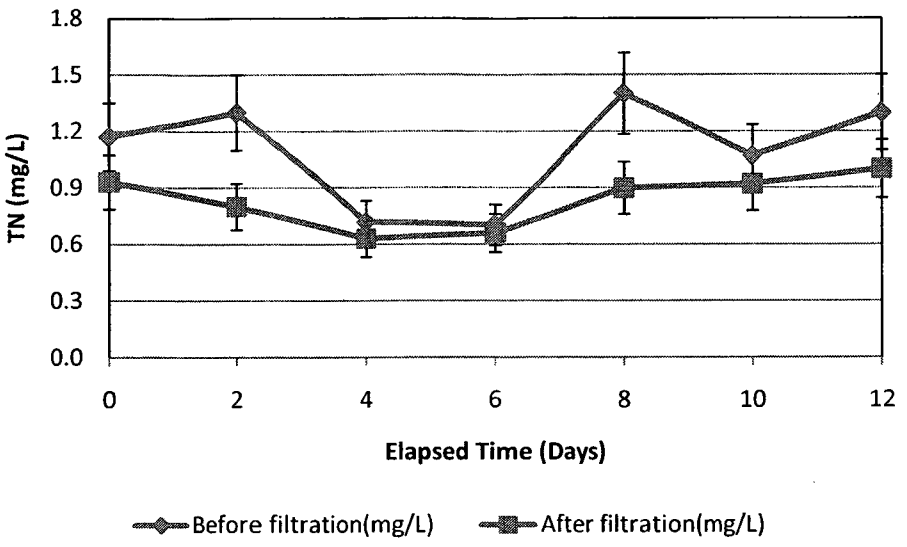


Figure 4-33 Changes in TN concentration by filter 7

4.5 Chemical oxygen demand

Figures 4-34 to 4-36 show the changes in the concentration of COD throughout filtration tests using LP filters. In the case of filter 1, due to the changes in the natural conditions as discussed in earlier section, good removal rate was not obtained. A decreasing trend was noticed for filters 2 and 3. Both SS and COD concentrations were high during this period of filtration with levels of 10 to 13.5 mg/L and 41.7 to 35 mg/L respectively. Although the concept of filter clogging justifies good filtration efficiency for high concentrations, filters 2 and 3 could perform fairly well in improving water quality in terms of COD reduction. Removal efficiencies of only 41.0% and 36.1% were obtained by filters 2 and 3 respectively. This could probably be due to the large portion of smaller solids which could have passed through the filter pores at the beginning because of the low retention capacity of the filters to retain solids. However, the filtration tests were running until the filter clogged to

see if any substantial removal occurs. The obtained efficiencies are because of the removal that occurred after clogging conditions.

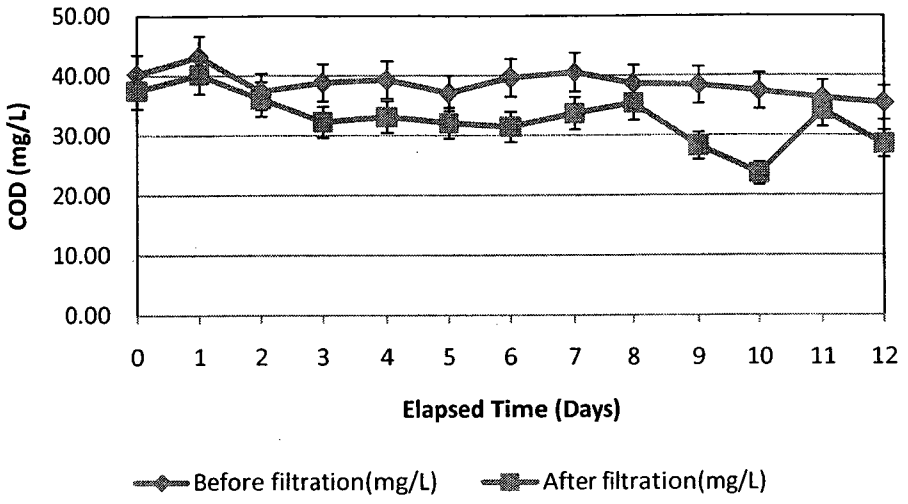


Figure 4-34 Changes in COD concentration by filter 1

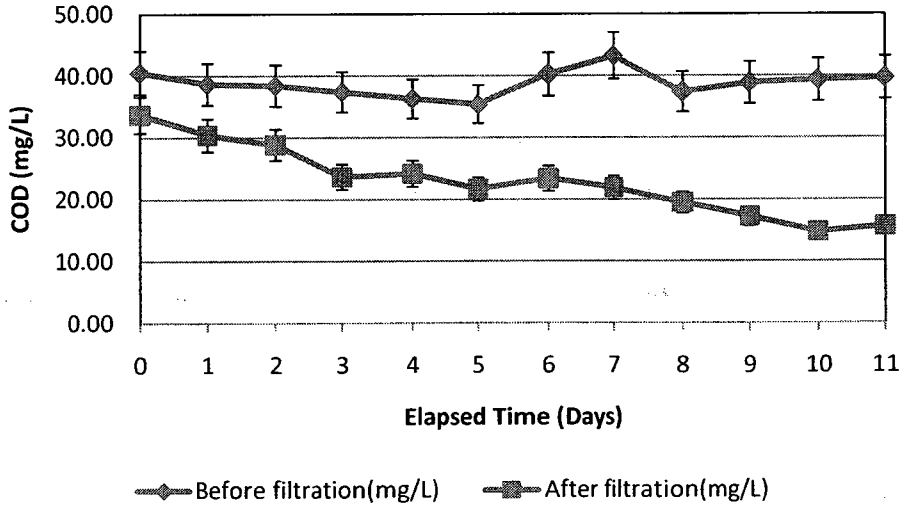


Figure 4-35 Changes in COD concentration by filter 2

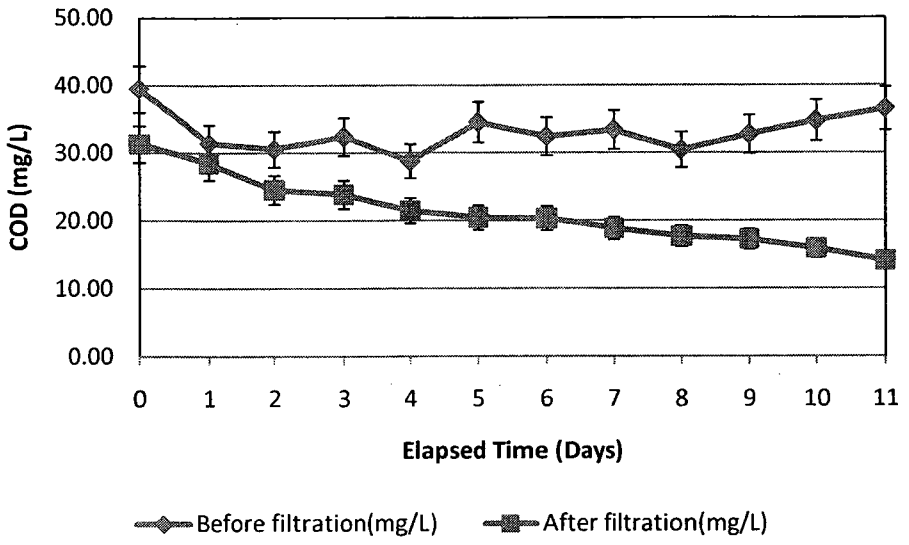


Figure 4- 36 Changes in COD concentration by filter 3

In the case of the GTX series of filters, these filters performed in a similar trend for reducing COD concentrations. However, filters 5 and 7 showed a better performance as compared to the rest of the filters. For Filter 5 with thickness of 0.36 cm and with 5 layers, a removal rate of 39.2% was achieved with 3 days of filtration. But with the early clogging because of the smaller opening size, the filtration was stopped within 5 days after filtration was started. One common trend observed in the case of the GTX filters, was that the concentration of COD was reduced along with the decrease of SS concentration. When filtration tests were started using filter 7, high concentrations of SS and COD (15.5 – 17 mg/L and 35.5 to 39 mg/L respectively) were measured. The rainfall that occurred might have increased the organic matter in the lake. With the thickness of 0.3cm, the filter had a good retention capacity of solids and because of this property, it could reduce the concentration of COD in the water sample. Removal efficiency of 49.6% was achieved using this filter. Although it doesn't seem be a great efficiency with the concentration of solids and COD present, the removal rate seems to be

fair enough. Figures 4-37 to 4-38 explains the changes in the COD levels by GTX series of filters.

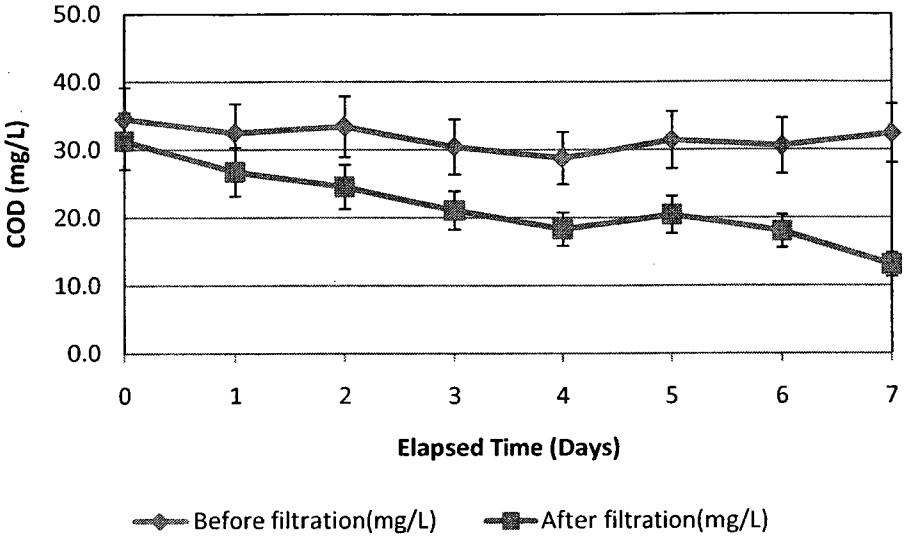


Figure 4-37 Changes in COD concentration by filter 4

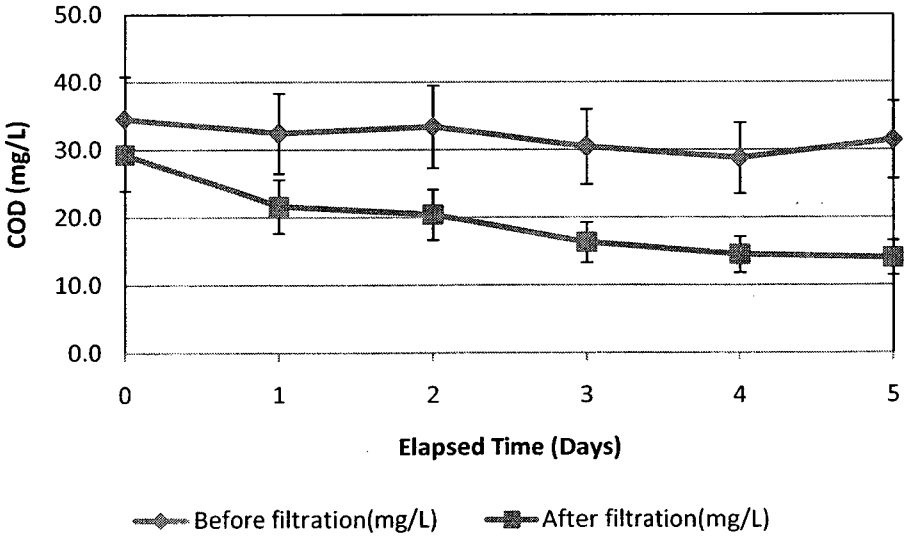


Figure 4-38 Changes in COD concentration by filter 5

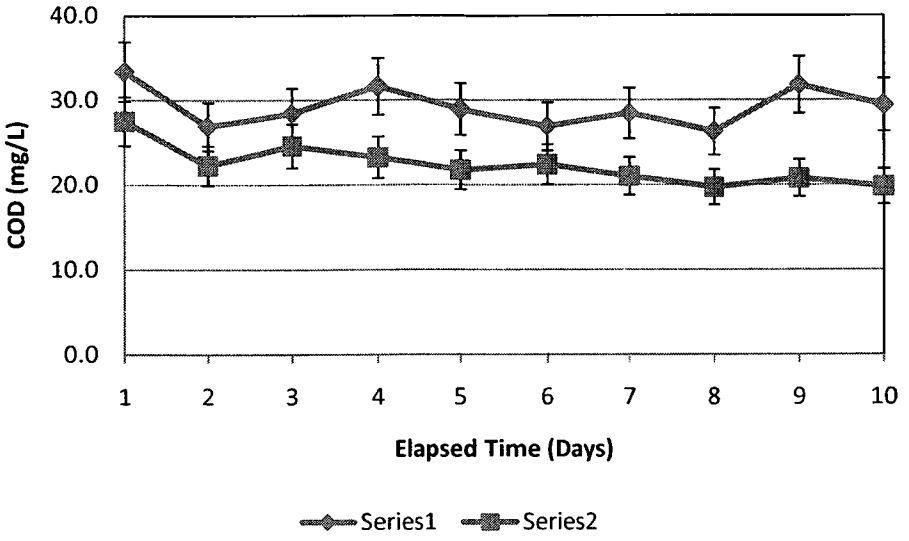


Figure 4-39 Changes in COD concentration by filter 6

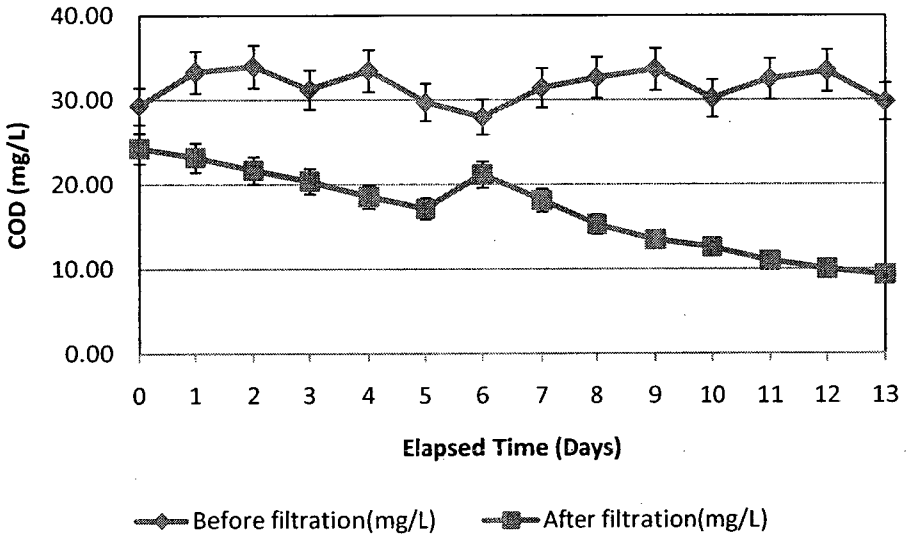


Figure 4-40 Changes in COD concentration by filter 7

4.6 Water quality based on total coliform count

In this study, classification of coliforms was done to assess if the water quality was safe enough for recreational purposes. MDDEP has classified water quality based on coliform levels for recreational uses. Based on this classification, to check the level of

contamination, samples from station 6 were analyzed weekly for coliform levels for the months October and November 2009 respectively. The water quality based on coliforms levels is as shown in Table 4-3.

As seen in the table, it seems that the lake water can be used for recreational uses, but with the approval from the governing authority. During early October, the value indicates high level contamination and any activities associated with that water should be prohibited. During the same time, samples from all the stations were tested too. Among six other conditions, station 2 and 3 showed a very bad quality with a coliform level of 1174 CFU/100 mL and 2424 CFU/100 mL, respectively. The samples from the rest of the stations were of mediocre level.

Table 4-3 Total coliform levels in Lake Caron

Sampling date	Total coliforms (CFU/100 mL)	Classification
October 8th	206	Poor
October 15th	188	Mediocre
October 24th	98	Good
November 4th	166	Mediocre
November 11th	141	Mediocre
November 16th	110	Mediocre

In addition, during the filtration tests with filter 7, some samples collected from after filtration were analyzed for coliform levels to check the filter ability for removing bacteria adhered to SS. A significant reduction in coliform levels was seen as filtration progressed. Table 4-4 shows the reduction levels in coliform in the filtrate.

Table 4-4 Coliform reduction levels in filtrate

Sampling date	Total coliforms (CFU/100 mL)	Classification
November 4th	123	Mediocre
November 11th	76	Good
November 16th	28	Good

4.7 Coefficient of Permeability

The permeability (k) of the filter was measured to study the reduction in filtration volume with respect to filtration time. It is clearly understood from the obtained results that good clogging condition favors good removal efficiency. Some of the factors that will influence clogging are the type of filter, initial SS value, pore size and the filtration rate proportional to k value (Mulligan et al., 2009). As seen in Figure 4-41, in the case of LP -12 although the k value decreased at first due to the initial SS value, as filtration progressed, it did not change drastically to bring about effective SS removal by clogging.

However, in the case of filters 4 and 5, the k value of the filter decreased rapidly within a few days; this is because of the premature clogging that had happened because of the smaller pore size of the filter. In the case of filter 6, although the smaller pore size contributed in clogging, the thickness factor prolongs the complete clogging of filter thereby increasing the SS concentration in the filtrate. Filter 7 showed good removal efficiency and this is because of the decrease in k value with time. The decrease in k was due to the clogging of the filter that reduced SS levels and eventually both total and dissolved phosphorus concentrations.

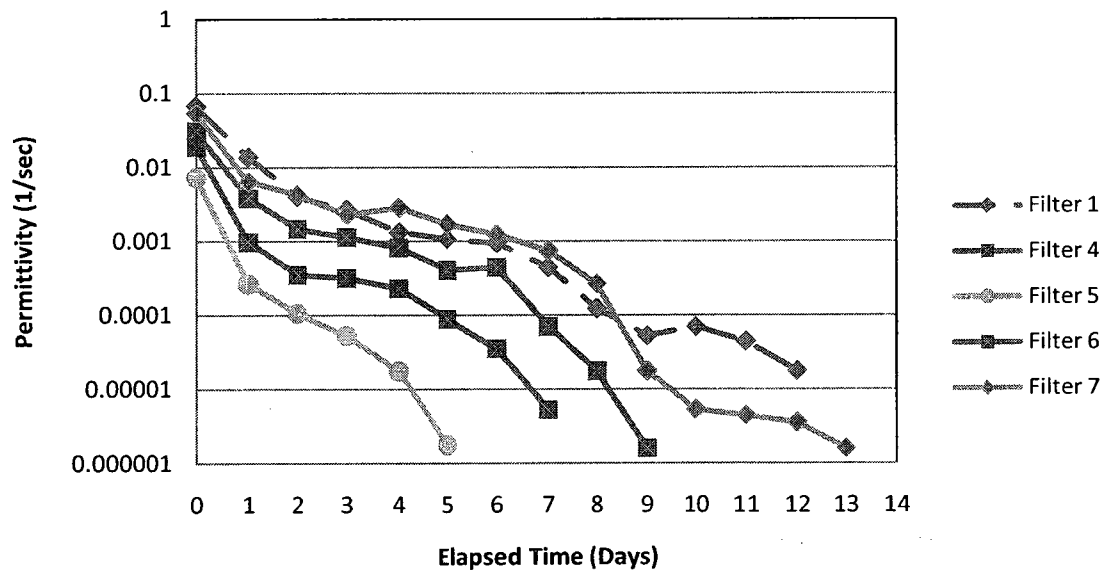


Figure 4-41 Coefficient of permeability (k) for all the filters

4.8 Cyanotoxin Analysis

With the growing concern of algal blooms at the lake, samples from station 6 and station 1 were sent to the Centre d'expertise en analyse Environnementale, Quebec to determine the type of the cyanobacteria that was present and the potential toxins associated with it.

The analysis reported the presence of toxin producing cyanobacteria such as *Microcystis, Coelosphaerim* and *Planktothrix* in between the range of 1000-5000 cells/ml. They also confirmed the presence of other classes of algae in abundance along with lot of debris in the sample [Refer to Appendix G]. No limits have been set or recommended for toxin producing cyanobacteria since the extent of which cyanobacteria blooms occurs across Canada is unknown. However, blooms containing even one species of toxic cyanobacteria are considered to be poisonous and potentially dangerous (Health Canada, 1992; Environment Canada, 2001). For many years, various studies have been conducted to investigate if the presence of Microcystis blooms had any influence on internal loading of P. The results obtained (Jacoby et al., 1982; Istavanovics, 1988; Xie et al., 2003) indicate the possibility of phosphorus release from the sediments by Microcystis blooms in eutrophic lakes. Thus, the presence of these blooms in Lake Caron attributes to the sudden increase and decrease in phosphorus concentration and one of the possible sources for internal loading.

4.9 Effect of water parameters on phosphorus release from sediments

Lake sediments contain much higher phosphorus levels than water and hence even a little amount of P released from sediments can lead to serious problems. Related environmental factors that have been identified for controlling sediment P release are temperature, pH, oxidation-reduction potential (ORP), nitrate and sulfate concentration, as well as biological activity (Christophidis and Fytianos, 2006). ORP is one of the most important parameters to describe the P adsorption onto the iron minerals in sediments. Phosphorus gets fixed at the surface of hydroxides of various metals such as Fe and Mn.

Studies have demonstrated that at low ORP (below 200 mV), part of the insoluble oxidized Fe(III) oxides and hydroxides are reduced to their soluble Fe(II) forms, thus releasing P sorbed on the surface and interiors of these compounds. The extent of this release is controlled by the redox value, availability of P binding sites and the presence of other redox active compounds such as nitrates and sulfates (Bostrom et al., 1982). Furthermore, it was observed that nitrates can increase the transfer of P from the sediments to the overlying water, acting as an alternative electron acceptor in biological processes (Bostrom et al., 1988).

Figure 4-42 shows the oxidation-reduction potential in the water column over the four months study period. During the first three weeks in August, the ORP dropped sharply from almost +150 mV to below +100 mV in the water. During this period, the phosphorus concentration in the lake water was very high and the values obtained were corresponding to a eutrophic lake. Gradually the phosphorus concentration in the water reduced and this explains the increase of ORP to +200 mV during the first week of October. In November, ORP suddenly dropped to +50 mV and a sudden increase in P concentration (0.092 mg/L) was observed. The variations in these values helped us to understand to some extent the role of water parameters in P internal loading. The dissolved oxygen (Figure 4-43) in the water dropped concurrently with the ORP during the first week of August. DO varied between 4 mg/L to 6 mg/L until September and raised above 7 mg/L and remained the same until the filtration was finished. However, all these variations can be better understood if the water-sediment interactions were studied in detail. At this point, these values were recorded just to understand the possible reasons for internal loading of P and growth leading to SS.

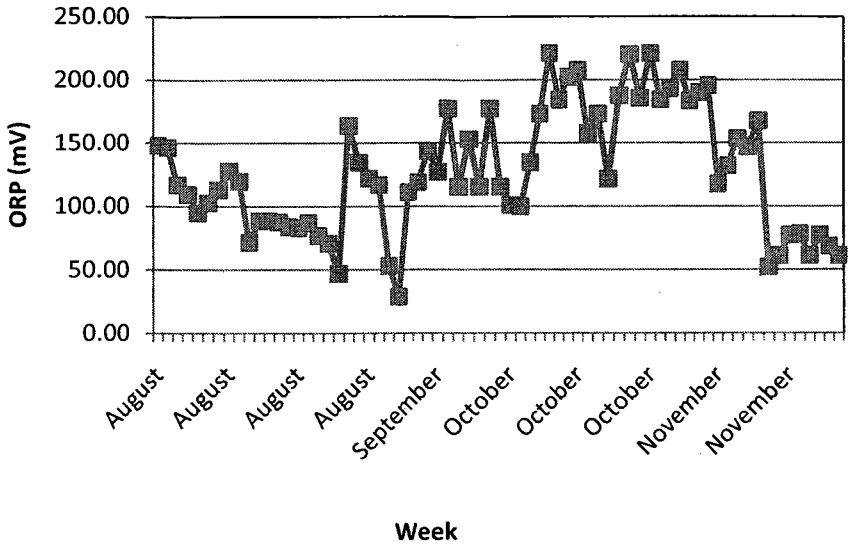


Figure 4-42 Daily oxidation-reduction potential measurements from Lake Caron

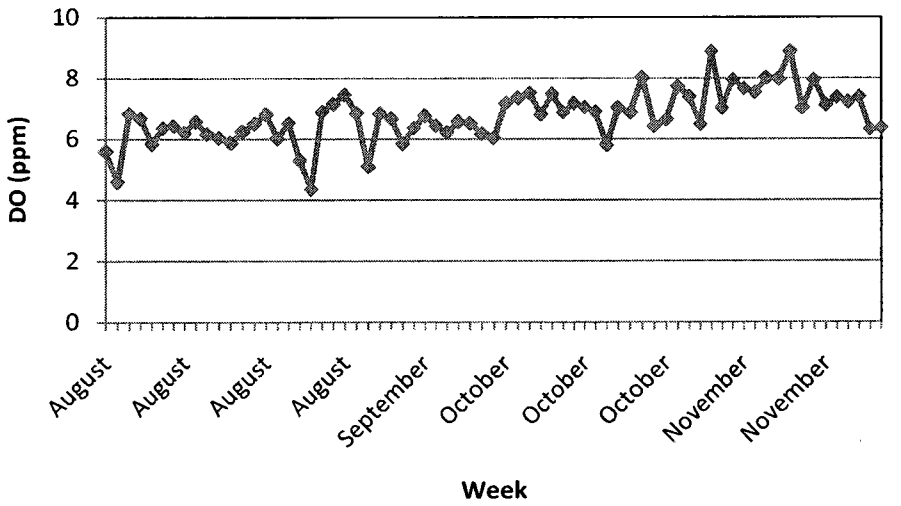


Figure 4-43 Daily dissolved oxygen measurements from Lake Caron

With the simple technique and the small in-situ set up at Lake Caron, the continuous filtration not only removed suspended solids but also reduced the levels of phosphorus in the water system. Based on the results obtained, this filtration unit can be used as one of the remediation technique for improving lake conditions.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The results obtained indicated the potential use of in-situ filtration tests at Lake Caron as an effective remediation technique for removing both suspended solids and phosphorus that have been impacted on an increased incidence of algal growth leading to eutrophication. In addition, the tests showed the possibility of making the lake a clean and safe place for public use for recreational activities.

Although Filter no's 7 and 1 had same AOS of 150 μm, it was observed that filter 7 showed 91% efficiency in removing SS as compared to 80% by filter 1. Thickness and permeability of the filters played a vital role in considering the removal efficiencies. GTX series of filters with AOS of 125 μm initially performed well in removing SS at faster rate but tended to clog rapidly. Furthermore, in-situ filtration tests showed considerable amount of removal of phosphorus (both total and dissolved forms) thereby establishing its effectiveness in controlling algal blooms as well.

In conclusion, GTX-250 with AOS 150 μm was found to be the most effective filter as compared to the rest of the filters used for removing contaminants in Lake Caron. This filtration tests are substantiated as an alternative remediation technique for improving surface water quality without using any chemicals or creating any environmental impact. Its transportable nature would make it a good remedial tool for treatment of problem

areas within a larger water body. However, the results obtained demand for further study of in-situ filtration since the contribution of the internal P load from the sediments seems to be remarkable in this shallow lake.

5.2 Recommendations for future work

Although the study was conducted successfully at the pilot scale level, few improvements can be made for better removal efficiency. In this context, future recommendations are as follows:

- To enhance SS removal efficiency, the filter media can be used in multiple layers of same type and/or with other different filter media type. For instance, the 150 μm filter can be used in conjunction with 125 μm as a bottom layer and this will help in achieving 100% removal.

- Evaluate SS removal in combination with a resuspension technique. By resuspending the sediment particles, the concentration of SS will increase and the ability of these solids to adsorb the contaminants will increase. This will help to reduce the organic matter at the bottom, surface sediments and aerate the bottom sediments (Mulligan et al., 2009).

  This resuspension can be achieved by using a stirring tank at the bottom of the water body, or stirring by emitting water jets or by mechanically disturbing sediments using rotating blades as shown in Figure 5-1.

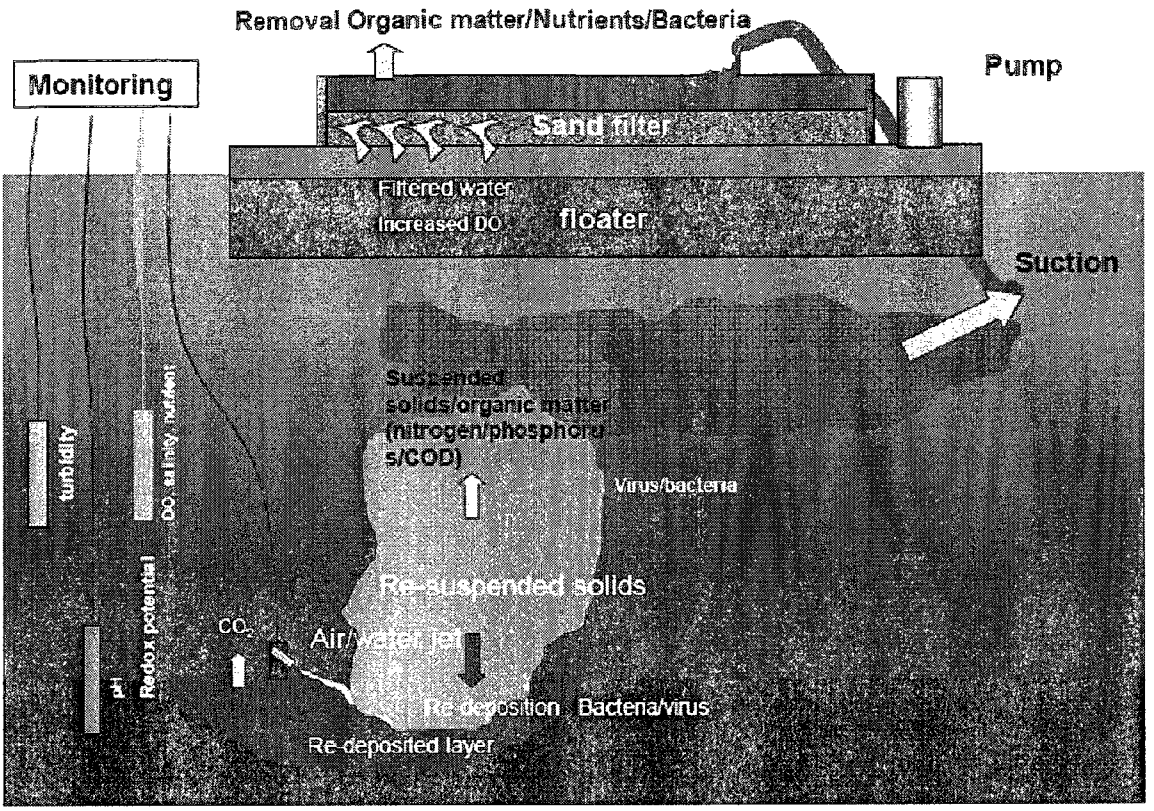


Figure 5-1 Illustrating resuspension technique with filtration system (adapted from Mulligan et al., 2009)

Knowing the fact that this technology will be an effective solution for improving the quality of water in Lake Caron, setting up a full-scale unit with the resuspension technique along with the good management strategy not only helps in restoring the aesthetic beauty of the lake but also serves the purpose which it is meant for (recreational activities).

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Appendix A

(A) Information on Lake Caron

Centre d'expertise hydrique
Québec

Bureau du directeur général

Nom du barrage: Barrage numéro 1577035029 - Lac Caron

Remarques : Par la rue Godefroy, Pinson et des Pétunias

Nom du réservoir: CARON

Municipalité(s)	M.R.C.	Région(s) administrative(s)
77035 Sainte-Anne-des-Lacs	Les Pays-d'en-Haut	Laurentides

Carte topographique			Coordonnées UTM NAD 83			Coordonnées degrés, minutes, secondes NAD 83	
Numéro	Échelle	Feuillet	Zone	X (Est)	Y (Nord)	Latitude	Longitude
31G16			18	566121,800	5076813,115	45° 50' 30,155"	74° 8' 54,577"

Hydrographie

Type	Numéro	Nom	Numéro	Nom bassin primaire
Bassin	04017000	BONNIEBROOK	04300000	OUTAOUAIS, RIVIÈRE DES
Lac	F3219	CARON, LAC	04300000	OUTAOUAIS, RIVIÈRE DES

Catégorie administrative:	Forte contenance	**Année de modification:**	1960
Année de construction:	1960	**Longueur (m):**	90,00
Année de modification:		**Revanche (m):**	0,20
Hauteur du barrage (m):	8,4		
Hauteur de retenue (m):	7,2		
Superficie du réservoir (ha):	3,54		
Superficie bassin versant (km²):	1,0		
Capacité de la retenue (m³):	50 200		

Appendix B

(B1) MDDEP Report on Lake Caron for the month of August 2009

Ministère du Développement durable, de l'Environnement et des Parcs
Québec

Mémo d'information sur les algues bleu-vert **N° 01 2009/09/03**

Région administrative : 15-Laurentides
Bassin versant : Rivière du Nord
Nom du plan d'eau : Lac Caron **Secteur :**
☒ **Carte ci-jointe** Latitude : 45,8398 Longitude : -74,1443

Destinataires	
Municipalité(s)	Nom du destinataire, fonction
Sainte Anne-des-Lacs	Jean François René, directeur général info@sadl.qc.ca
	Frédéric Girard, inspecteur municipal env@sadl.qc.ca

Observations générales (2009/08/28)

Fleur d'eau d'algues bleu-vert de catégorie 2a présentant une légère coloration verte observable sur l'ensemble du lac. Une écume d'algues bleu-vert (catégorie 2b) de coloration verte était observable à 6 endroits sur le plan d'eau. La superficie totale recouverte par l'écume s'élevait à environ 62,6 m², soit 0,6 % du lac qui a une superficie totale de 1 ha. Il n'y aurait pas de prise d'eau individuelle prélevant l'eau du lac. Quelques riverains y pratiquent la baignade.

Observations aux stations d'échantillonnage et résultats d'analyses du laboratoire

Station : A	**Type de prélèvement :** Échantillon de surface	
Observations visuelles Échantillon prélevé dans une écume d'algues bleu-vert (catégorie 2b) d'une superficie estimée à 10 m² dans le secteur ouest du lac.		
Cyanobactéries :	Totales : > **2 000 000 cellules/ml** À potentiel toxique : > **2 000 000 cellules/ml**	
Cyanotoxines :	Microcystine-LR (toxicité équivalente) : **63 µg/l**	non détectée ☐
	Anatoxine-a : µg/l	non détectée ☒

Station : B	**Type de prélèvement :** Tube 0-1m	
Observations visuelles Échantillon d'une colonne d'eau prélevé dans une fleur d'eau de catégorie 2a dans le centre ouest du lac, représentatif de l'état généralisé du lac. L'échantillon a été prélevé à environ 30 mètres d'une écume d'algues bleu-vert.		
Cyanobactéries :	Totales : 100 000 – 500 000 **cellules/ml** À potentiel toxique : 100 000 – 500 000 **cellules/ml**	
Cyanotoxines :	Microcystine-LR (toxicité équivalente) : **3,1 µg/l**	non détectée ☐
	Anatoxine-a : µg/l	non détectée ☒

Station :	**Type de prélèvement :**	
Observations visuelles		
Cyanobactéries :	Totales : cellules/ml À potentiel toxique : cellules/ml	
Cyanotoxines :	Microcystine-LR (toxicité équivalente) : µg/l	non détectée ☐
	Anatoxine-a : µg/l	non détectée ☐

Ministère du Développement durable, de l'Environnement et des Parcs
Québec

Interprétation des résultats d'analyses

☐	*Autre phénomène (autres types d'algues, pollen, etc.)* *Observations :*
☐	***Cote A :*** *Les résultats d'analyse des échantillons prélevés dans le plan d'eau ont démontré que la densité de cyanobactéries totales[1] était inférieure à 20 000 cellules/ml. Une densité aussi faible n'est pas considérée comme une fleur d'eau.* *Cette situation ne requiert pas une intervention de santé publique.* ***Suivi visuel volontaire*** *effectué par :* *souhaité (volontaires recherchés)* ☐
☐	***Cote B :*** *Les résultats d'analyse ont confirmé la présence de cyanobactéries totales[1] dans les échantillons prélevés dans le plan d'eau à une densité supérieure à 20 000 cellules/ml. Il s'agissait donc d'une fleur d'eau de cyanobactéries.* *Cette situation ne requiert pas une intervention de santé publique.* ***Suivi visuel volontaire*** *effectué par :* *souhaité (volontaires recherchés)* ☐
☒	***Cote C :*** *Les résultats d'analyse des échantillons prélevés dans le plan d'eau ont confirmé que la densité de cyanobactéries totales était supérieure à 20 000 cellules/ml. Il s'agissait donc d'une fleur d'eau de cyanobactéries. De plus, au moins un résultat en cyanotoxines dans la fleur d'eau, dépasse un des seuils visant à protéger l'usage le plus sensible (baignade ou eau potable) de votre plan d'eau* *Les informations sur la localisation, l'étendue de la fleur d'eau ainsi que les résultats d'analyses ont été transmis à la DSP. À la suite d'une évaluation de l'ensemble de la situation, la DSP informera la municipalité de sa décision et des mesures particulières à prendre, s'il y a lieu.* *Suivi visuel volontaire effectué par :* *souhaité (volontaires recherchés)* ☒
Prochaine visite (s'il y a lieu) : Au cours de la semaine du 2009/09/08	

Actions à prendre par le destinataire

- Retourner, à l'expéditeur du mémo d'information, un **message <u>non automatisé</u>** confirmant la réception du mémo N° **01**
- Assurer si possible un **suivi visuel** de ce plan d'eau et effectuer un nouveau signalement au MDDEP si l'étendue ou l'intensité de la fleur d'eau s'accroît de façon importante. Nous informer s'il y a lieu d'un nouveau partenaire pour le suivi visuel.

<u>Actions supplémentaires pour les cotes B et C</u>

- ***Les recommandations générales en présence d'une fleur d'eau s'appliquent en tout temps. Ces recommandations se trouvent à l'adresse suivante :***
  http://www.msss.gouv.qc.ca/sujets/santepub/environnement/index.php?algues_bleu-vert
- Aviser le coordonnateur des mesures d'urgence ainsi que l'opérateur de la station de traitement de la présence de fleur d'eau de cyanobactéries dans le plan d'eau si celui-ci est utilisé comme source d'approvisionnement en eau potable
- Informer les exploitants de plages organisées localisées sur les rives du plan d'eau

Pour protéger un plan d'eau, prévenir ou réduire l'eutrophisation comme le développement d'une fleur d'eau de cyanobactéries, nous vous invitons à appliquer différentes mesures à l'échelle du bassin versant telles que protéger les rives et réduire les apports en phosphore.

Informations supplémentaires sur les algues bleu-vert et la protection des plans d'eau

Consulter le Portail national de l'information gouvernementale :
http://www.baguesbleuvert.gouv.qc.ca/fr/index.asp

Direction régionale du MDDEP : Personne à contacter : Isabelle Dorion	Tél. : 450 433-2220 poste 280
Direction de santé publique (DSP) : Personne à contacter : Bruno Cossette	Tél. : 450 432-8735 poste

[1] **Cyanobactéries totales:** Ensemble des genres dominants de cyanobactéries présents dans l'échantillon. Les cyanobactéries totales regroupent donc les genres susceptibles de produire des toxines et les autres cyanobactéries.

(B2) MDDEP Report on Lake Caron for the month of September 2009

Ministère du Développement durable, de l'Environnement et des Parcs
Québec

Mémo d'information sur les algues bleu-vert **N° 02** 2009/09/18

Région administrative : **15-Laurentides**
Bassin versant : Rivière du Nord
Nom du plan d'eau : Lac Caron **Secteur :**
☒ **Carte ci-jointe** Latitude : 45,8398 Longitude : -74,1443

Destinataires

Municipalité(s)	Nom du destinataire, fonction
Sainte-Anne-des-Lacs	Jean-François René, directeur général info@sadl.qc.ca
	Frédéric Girard, inspecteur municipal env@sadl.qc.ca

Observations générales (2009/09/16)

Fleur d'eau d'algues bleu-vert de catégorie 1 très près d'une catégorie 2a sur l'ensemble du lac. Lors des observations le vent est assez fort et crée de nombreuses vagues à la surface.
Une petite zone de catégorie 2b est visible dans la baie au sud du lac. Elle couvre 2 mètres carrés. De plus grosses particules sont visibles dans la colonne d'eau dans la partie nord-est du lac. Cette zone couvre 10 à 15% du lac.

Observations aux stations d'échantillonnage et résultats d'analyses du laboratoire

Station : A	**Type de prélèvement :** Échantillon de surface	
Observations visuelles Échantillon prélevé dans une écume d'algues bleu-vert (catégorie 2b) d'une superficie estimée à 2 m² dans le secteur sud du lac.		
Cyanobactéries :	Totales : **>2 000 000 cellules/ml** À potentiel toxique : **>2 000 000 cellules/ml**	
Cyanotoxines :	Microcystine-LR (toxicité équivalente) : **16 µg/l**	non détectée ☐
	Anatoxine-a : **µg/l**	non détectée ☒

Station : B	**Type de prélèvement :** Tube 0-1m	
Observations visuelles Échantillon d'une colonne d'eau prélevé dans une fleur d'eau de catégorie 1 dans le secteur nord-est du lac. L'échantillon a été prélevé dans une zone où se trouve de nombreuses particules plus grosses.		
Cyanobactéries :	Totales : **100 000 - 500 000 cellules/ml** À potentiel toxique : **100 000 - 500 000 cellules/ml**	
Cyanotoxines :	Microcystine-LR (toxicité équivalente) : **3.3 µg/l**	non détectée ☐
	Anatoxine-a : **µg/l**	non détectée ☒

Station : C	**Type de prélèvement :** Tube 0-1m	
Observations visuelles Échantillon d'une colonne d'eau prélevé dans une fleur d'eau représentant la condition générale du lac. L'échantillon a été pris dans le secteur ouest du lac.		
Cyanobactéries :	Totales : **20 000 - 50 000 cellules/ml** À potentiel toxique : **20 000 - 50 000 cellules/ml**	
Cyanotoxines :	Microcystine-LR (toxicité équivalente) : **0.85 µg/l**	non détectée ☐
	Anatoxine-a : **µg/l**	non détectée ☒

Ministère du Développement durable, de l'Environnement et des Parcs
Québec

Interprétation des résultats d'analyses

☐	*Autre phénomène (autres types d'algues, pollen, etc.)* *Observations :*
☐	***Cote A :*** *Les résultats d'analyse des échantillons prélevés dans le plan d'eau ont démontré que la densité de cyanobactéries totales[1] était inférieure à 20 000 cellules/ml. Une densité aussi faible n'est pas considérée comme une fleur d'eau.* *Cette situation ne requiert pas une intervention de santé publique.* ***Suivi visuel volontaire*** *effectué par :* *souhaité (volontaires recherchés)* ☐
☐	***Cote B :*** *Les résultats d'analyse ont confirmé la présence de cyanobactéries totales[1] dans les échantillons prélevés dans le plan d'eau à une densité supérieure à 20 000 cellules/ml. Il s'agissait donc d'une fleur d'eau de cyanobactéries.* *Cette situation ne requiert pas une intervention de santé publique.* ***Suivi visuel volontaire*** *effectué par :* *souhaité (volontaires recherchés)* ☐
☒	***Cote C :*** *Les résultats d'analyse des échantillons prélevés dans le plan d'eau ont confirmé que la densité de cyanobactéries totales était supérieure à 20 000 cellules/ml. Il s'agissait donc d'une fleur d'eau de cyanobactéries. De plus, au moins un résultat en cyanotoxines dans la fleur d'eau, dépasse un des seuils visant à protéger l'usage le plus sensible (baignade ou eau potable) de votre plan d'eau* *Les informations sur la localisation, l'étendue de la fleur d'eau ainsi que les résultats d'analyses ont été transmis à la DSP. À la suite d'une évaluation de l'ensemble de la situation, la DSP informera la municipalité de sa décision et des mesures particulières à prendre, s'il y a lieu.* ***Suivi visuel volontaire*** *effectué par :* *souhaité (volontaires recherchés)* ☒
Prochaine visite (s'il y a lieu) : Suite à l'observation par la vigie d'une amélioration notable.	

Actions à prendre par le destinataire

- Retourner, à l'expéditeur du mémo d'information, un **message <u>non automatisé</u>** confirmant la réception du mémo N° **01**
- Assurer si possible un **suivi visuel** de ce plan d'eau et effectuer un nouveau signalement au MDDEP si l'étendue ou l'intensité de la fleur d'eau s'accroît de façon importante. Nous informer s'il y a lieu d'un nouveau partenaire pour le suivi visuel.

<u>Actions supplémentaires pour les cotes B et C</u>

- ***Les recommandations générales en présence d'une fleur d'eau s'appliquent en tout temps. Ces recommandations se trouvent à l'adresse suivante :***
  http://www.msss.gouv.qc.ca/sujets/santepub/environnement/index.php?algues_bleu-vert
- Aviser le coordonnateur des mesures d'urgence ainsi que l'opérateur de la station de traitement de la présence de fleur d'eau de cyanobactéries dans le plan d'eau si celui-ci est utilisé comme source d'approvisionnement en eau potable
- Informer les exploitants de plages organisées localisées sur les rives du plan d'eau

Pour protéger un plan d'eau, prévenir ou réduire l'eutrophisation comme le développement d'une fleur d'eau de cyanobactéries, nous vous invitons à appliquer différentes mesures à l'échelle du bassin versant telles que protéger les rives et réduire les apports en phosphore.

Informations supplémentaires sur les algues bleu-vert et la protection des plans d'eau

Consulter le Portail national de l'information gouvernementale :
http://www.alguesbleuvert.gouv.qc.ca/fr/index.asp

Direction régionale du MDDEP : Personne à contacter : Isabelle Dorion	Tél. : 450 433-2220 poste 280
Direction de santé publique (DSP) : Personne à contacter : Bruno Cossette	Tél. : 450 432-8735 poste

[1] **Cyanobactéries totales:** Ensemble des genres dominants de cyanobactéries présents dans l'échantillon. Les cyanobactéries totales regroupent donc les genres susceptibles de produire des toxines et les autres cyanobactéries.

(B3) MDDEP Report on Lake Caron for the month of October 2009

Ministère du Développement durable, de l'Environnement et des Parcs
Québec

Mémo d'information sur les algues bleu-vert — **N° 03** — **2009/10/26**

Région administrative : 15-Laurentides
Bassin versant : Rivière du Nord
Nom du plan d'eau : Lac Caron — **Secteur :**
☒ **Carte ci-jointe** — Latitude : 45,8398 — Longitude : -74,1443

Destinataires	
Municipalité(s)	**Nom du destinataire, fonction**
Sainte-Anne-des-Lacs	Jean-François René, directeur général info@sadl.qc.ca
	Frédéric Girard, inspecteur municipal env@sadl.qc.ca

Observations générales (2009/10/21)

Particules vertes en suspension dans la colonne d'eau (catégorie 1 faible) observable sur l'ensemble du lac. Environ 50% des rives présentaient une concentration de particules vertes en suspension dans la colonne d'eau plus intense (catégorie 1). La baie située au sud du lac présentait en rive une écume d'algue bleu-vert (catégorie 2b) sur environ 50 mètres de longueur par 1,75 mètres en moyenne de largeur. Le secteur est du lac présentait également une écume (catégorie 2b) sur environ 70 mètres de longueur par 1 mètre de largeur.

Les riverains qui prélèvent l'eau directement du lac ne l'utiliseraient, selon les personnes rencontrées, que pour l'arrosage des pelouses. Il n'y aurait pas d'usages domestiques de cette eau.

Observations aux stations d'échantillonnage et résultats d'analyses du laboratoire

Station : D	**Type de prélèvement :** Échantillon de surface	
Observations visuelles Échantillon prélevé dans une fleur d'eau d'algues bleu-vert de catégorie 1 intense dans le secteur nord du lac.		
Cyanobactéries :	Totales : **5 000-10 000 cellules/ml** À potentiel toxique : **5 000-10 000 cellules/ml**	
Cyanotoxines :	Microcystine-LR (toxicité équivalente) : **0,61 µg/l**	non détectée ☐
	Anatoxine-a : **µg/l**	non détectée ☒

Station : E	**Type de prélèvement :** Tube 0-1m	
Observations visuelles Échantillon d'une colonne d'eau prélevé dans une fleur d'eau de catégorie 1 faible dans le secteur centre ouest du lac, représentative de l'état général du lac.		
Cyanobactéries :	Totales : **5 000-10 000 cellules/ml** À potentiel toxique : **2 000-5 000 cellules/ml**	
Cyanotoxines :	Microcystine-LR (toxicité équivalente) : **0,35 µg/l**	non détectée ☐
	Anatoxine-a : **µg/l**	non détectée ☒

Station : H	**Type de prélèvement :** Échantillon de surface	
Observations visuelles Échantillon prélevé dans une écume d'algues bleu-vert (catégorie 2b) d'une superficie d'environ 87,5 m² dans la baie située au sud du lac. Les secteurs affectés par une écume d'algues bleu-vert (catégorie 2b) recouvrent une superficie totale de 157,5 m² et sont situés au sud et à l'est du lac.		
Cyanobactéries :	Totales : **> 2 000 000 cellules/ml** À potentiel toxique : **> 2 000 000 cellules/ml**	
Cyanotoxines :	Microcystine-LR (toxicité équivalente) : **510 µg/l**	non détectée ☐
	Anatoxine-a : **µg/l**	non détectée ☒

Ministère du Développement durable, de l'Environnement et des Parcs
Québec

Interprétation des résultats d'analyses

☐	*Autre phénomène (autres types d'algues, pollen, etc.)* *Observations :*
☐	***Cote A :*** *Les résultats d'analyse des échantillons prélevés dans le plan d'eau ont démontré que la densité de cyanobactéries totales[1] était inférieure à 20 000 cellules/ml. Une densité aussi faible n'est pas considérée comme une fleur d'eau.* *Cette situation ne requiert pas une intervention de santé publique.* ***Suivi visuel volontaire*** *effectué par :* *souhaité (volontaires recherchés)* ☐
☐	***Cote B :*** *Les résultats d'analyse ont confirmé la présence de cyanobactéries totales[1] dans les échantillons prélevés dans le plan d'eau à une densité supérieure à 20 000 cellules/ml. Il s'agissait donc d'une fleur d'eau de cyanobactéries.* *Cette situation ne requiert pas une intervention de santé publique.* ***Suivi visuel volontaire*** *effectué par :* *souhaité (volontaires recherchés)* ☐
☒	***Cote C :*** *Les résultats d'analyse des échantillons prélevés dans le plan d'eau ont confirmé que la densité de cyanobactéries totales était supérieure à 20 000 cellules/ml. Il s'agissait donc d'une fleur d'eau de cyanobactéries. De plus, au moins un résultat en cyanotoxines dans la fleur d'eau, dépasse un des seuils visant a protéger l'usage le plus sensible (baignade ou eau potable) de votre plan d'eau* *Les informations sur la localisation, l'étendue de la fleur d'eau ainsi que les résultats d'analyses ont été transmis à la DSP. À la suite d'une évaluation de l'ensemble de la situation, la DSP informera la municipalité de sa décision et des mesures particulières à prendre, s'il y a lieu.* ***Suivi visuel volontaire*** *effectué par :* *souhaité (volontaires recherchés)* ☒
Prochaine visite (s'il y a lieu) : Selon les observations visuelles rapportées	

Actions à prendre par le destinataire

- Retourner, à l'expéditeur du mémo d'information, un **message <u>non automatisé</u>** confirmant la réception du mémo N° **03**
- Assurer si possible un **suivi visuel** de ce plan d'eau et effectuer un nouveau signalement au MDDEP si l'étendue ou l'intensité de la fleur d'eau s'accroît de façon importante. Nous informer s'il y a lieu d'un nouveau partenaire pour le suivi visuel.

<u>Actions supplémentaires pour les cotes B et C</u>

- ***Les recommandations générales en présence d'une fleur d'eau s'appliquent en tout temps. Ces recommandations se trouvent à l'adresse suivante :***
  <u>http://www.msss.gouv.qc.ca/sujets/santepub/environnement/index.php?algues_bleu-vert</u>
- Aviser le coordonnateur des mesures d'urgence ainsi que l'opérateur de la station de traitement de la présence de fleur d'eau de cyanobactéries dans le plan d'eau si celui-ci est utilisé comme source d'approvisionnement en eau potable
- Informer les exploitants de plages organisées localisées sur les rives du plan d'eau

Pour protéger un plan d'eau, prévenir ou réduire l'eutrophisation comme le développement d'une fleur d'eau de cyanobactéries, nous vous invitons à appliquer différentes mesures à l'échelle du bassin versant telles que protéger les rives et réduire les apports en phosphore.

Informations supplémentaires sur les algues bleu-vert et la protection des plans d'eau

Consulter le Portail national de l'information gouvernementale :
<u>http://www.alguesbleuvert.gouv.qc.ca/fr/index.asp</u>

Direction régionale du MDDEP : Personne à contacter : Isabelle Dorion	Tél. : 450 433-2220 poste 280
Direction de santé publique (DSP) : Personne à contacter : Bruno Cossette	Tél. : 450 432-8735 poste

[1] Cyanobactéries totales: Ensemble des genres dominants de cyanobactéries présents dans l'échantillon. Les cyanobactéries totales regroupent donc les genres susceptibles de produire des toxines et les autres cyanobactéries.

(B4) MDDEP Report on Lake Caron for the month of November 2009

Ministère du Développement durable, de l'Environnement et des Parcs
Québec

Mémo d'information sur les algues bleu-vert — **N° 04** — 2009/11/17

Région administrative :	**15-Laurentides**	
Bassin versant :	Rivière du Nord	
Nom du plan d'eau :	Lac Caron	**Secteur :**
☒ **Carte ci-jointe**	Latitude : 45,8398	Longitude : -74,1443

Destinataires

Municipalité(s)	Nom du destinataire, fonction
Sainte-Anne-des-Lacs	Jean-François René, directeur général info@sadl.qc.ca
	Frédéric Girard, inspecteur municipal env@sadl.qc.ca

Observations générales (2009/11/11)

Fleur d'eau observable en suspension dans la colonne d'eau (catégorie 1) sur l'ensemble du lac. Une fleur d'eau de catégorie 1 plus intense était observable sur environ le tiers de la superficie du lac. Les baies situées au sud et à l'est du lac présentaient en rive une écume d'algues bleu-vert (catégorie 2b) qui recouvrait environ 16 m² au total. Ces deux baies étaient couvertes partiellement d'une mince couche de glace qui emprisonnait les écumes.

Observations aux stations d'échantillonnage et résultats d'analyses du laboratoire

Station : D	**Type de prélèvement :** Tube 0-1m	
Observations visuelles Échantillon d'une colonne d'eau prélevé dans une fleur d'eau de catégorie 1 intense, baie nord du lac.		
Cyanobactéries :	Totales : **2 000-5 000 cellules/ml** À potentiel toxique : **2 000-5 000 cellules/ml**	
Cyanotoxines :	Microcystine-LR (toxicité équivalente) : 0,29 **µg/l**	non détectée ☐
	Anatoxine-a : **µg/l**	non détectée ☒

Station : H	**Type de prélèvement :** Échantillon de surface	
Observations visuelles Échantillon d'une écume dense d'algues bleu-vert (catégorie 2b) prélevé dans la baie située au sud du lac. L'écume dense échantillonnée présentait une superficie de 0,16 m². Un mince couvert de glace recouvrait la baie. Une écume éparse (catégorie 2b) était aussi observable dans cette baie, sous la glace, sur une superficie de 12 m².		
Cyanobactéries :	Totales : **> 2 000 000 cellules/ml** À potentiel toxique : **> 2 000 000 cellules/ml**	
Cyanotoxines :	Microcystine-LR (toxicité équivalente) : 27 **µg/l**	non détectée ☐
	Anatoxine-a : **µg/l**	non détectée ☒

Station : Z	**Type de prélèvement :** Tube 0-1m	
Observations visuelles Échantillon d'une colonne d'eau prélevé dans une fleur d'eau de catégorie 1, secteur ouest du lac. La fleur d'eau est représentative de l'état général du lac.		
Cyanobactéries :	Totales : **1-1000 cellules/ml** À potentiel toxique : **1-1000 cellules/ml**	
Cyanotoxines :	Microcystine-LR (toxicité équivalente) : 0,60 **µg/l**	non détectée ☐
	Anatoxine-a : **µg/l**	non détectée ☒

Ministère du Développement durable, de l'Environnement et des Parcs
Québec

Interprétation des résultats d'analyses

☐	*Autre phénomène (autres types d'algues, pollen, etc.)* *Observations :*
☐	***Cote A :*** *Les résultats d'analyse des échantillons prélevés dans le plan d'eau ont démontré que la densité de cyanobactéries totales[1] était inférieure à 20 000 cellules/ml. Une densité aussi faible n'est pas considérée comme une fleur d'eau.* *Cette situation ne requiert pas une intervention de santé publique.* ***Suivi visuel volontaire*** *effectué par :* *souhaité (volontaires recherchés)* ☐
☐	***Cote B :*** *Les résultats d'analyse ont confirmé la présence de cyanobactéries totales[1] dans les échantillons prélevés dans le plan d'eau à une densité supérieure à 20 000 cellules/ml. Il s'agissait donc d'une fleur d'eau de cyanobactéries.* *Cette situation ne requiert pas une intervention de santé publique.* ***Suivi visuel volontaire*** *effectué par :* *souhaité (volontaires recherchés)* ☐
☒	***Cote C :*** *Les résultats d'analyse des échantillons prélevés dans le plan d'eau ont confirmé que la densité de cyanobactéries totales était supérieure à 20 000 cellules/ml. Il s'agissait donc d'une fleur d'eau de cyanobactéries. De plus, au moins un résultat en cyanotoxines dans la fleur d'eau, dépasse un des seuils visant à protéger l'usage le plus sensible (baignade ou eau potable) de votre plan d'eau* *Les informations sur la localisation, l'étendue de la fleur d'eau ainsi que les résultats d'analyses ont été transmis à la DSP. À la suite d'une évaluation de l'ensemble de la situation, la DSP informera la municipalité de sa décision et des mesures particulières à prendre, s'il y a lieu.* ***Suivi visuel volontaire*** *effectué par :* *souhaité (volontaires recherchés)* ☒
Prochaine visite (s'il y a lieu) : Selon les observations visuelles rapportées	

Actions à prendre par le destinataire

- Retourner, à l'expéditeur du mémo d'information, un **message <u>non automatisé</u>** confirmant la réception du mémo N° **04**
- Assurer si possible un **suivi visuel** de ce plan d'eau et effectuer un nouveau signalement au MDDEP si l'étendue ou l'intensité de la fleur d'eau s'accroît de façon importante. Nous informer s'il y a lieu d'un nouveau partenaire pour le suivi visuel.

<u>Actions supplémentaires pour les cotes B et C</u>

- ***Les recommandations générales en présence d'une fleur d'eau s'appliquent en tout temps. Ces recommandations se trouvent à l'adresse suivante :***
  <u>http://www.msss.gouv.qc.ca/sujets/santepub/environnement/index.php?algues_bleu-vert</u>
- Aviser le coordonnateur des mesures d'urgence ainsi que l'opérateur de la station de traitement de la présence de fleur d'eau de cyanobactéries dans le plan d'eau si celui-ci est utilisé comme source d'approvisionnement en eau potable.
- Informer les exploitants de plages organisées localisées sur les rives du plan d'eau.

Pour protéger un plan d'eau, prévenir ou réduire l'eutrophisation comme le développement d'une fleur d'eau de cyanobactéries, nous vous invitons à appliquer différentes mesures à l'échelle du bassin versant telles que protéger les rives et réduire les apports en phosphore.

Informations supplémentaires sur les algues bleu-vert et la protection des plans d'eau

Consulter le Portail national de l'information gouvernementale : <u>http://www.alguesbleuvert.gouv.qc.ca/fr/index.asp</u>	
Direction régionale du MDDEP : Personne à contacter : Isabelle Dorion	Tél. : 450 433-2220 poste 280
Direction de santé publique (DSP) : Personne à contacter : Bruno Cossette	Tél. : 450 432-8735 poste

[1] **Cyanobactéries totales:** Ensemble des genres dominants de cyanobactéries présents dans l'échantillon. Les cyanobactéries totales regroupent donc les genres susceptibles de produire des toxines et les autres cyanobactéries.

(B5) MDDEP Report on Lake Caron for the month of December 2009

Ministère du Développement durable, de l'Environnement et des Parcs
Québec

Mémo d'information sur les algues bleu-vert — **N° 05** — 2009/12/02

Région administrative : **15-Laurentides**
Bassin versant : Rivière du Nord
Nom du plan d'eau : Lac Caron — **Secteur :**
☒ **Carte ci-jointe** Latitude : 45,8398 — Longitude : -74,1443

Destinataires

Municipalité(s)	Nom du destinataire, fonction
Sainte-Anne-des-Lacs	Jean-François René, directeur général info@sadl.qc.ca
	Frédéric Girard, inspecteur municipal env@sadl.qc.ca

Observations générales (2009/11/25)

Particules jaunâtres en faible quantité observables en suspension dans la colonne d'eau sur l'ensemble du lac (catégorie 1 très faible). Les baies situées au sud et à l'ouest du lac présentaient en rive des écumes très limitées d'algues bleu-vert (catégorie 2b) qui recouvraient environ 2,12 m² au total. Les observations ont été relevées à partir de la rive.

Observations aux stations d'échantillonnage et résultats d'analyses du laboratoire

Station : CAR-E		**Type de prélèvement :** Échantillon de surface
Observations visuelles Échantillon prélevé dans une fleur d'eau de catégorie 1, secteur ouest du lac. Cette fleur d'eau était localisée à environ 6 mètres d'une écume éparse. Les vents dirigeaient les eaux vers cette extrémité du lac.		
Cyanobactéries :	Totales : **1-1000 cellules/ml** À potentiel toxique : **1-1000 cellules/ml**	
Cyanotoxines :	Microcystine-LR (toxicité équivalente) : 0,37 **µg/l**	non détectée ☐
	Anatoxine-a : **µg/l**	non détectée ☒

Station : CAR-H		**Type de prélèvement :** Échantillon de surface
Observations visuelles Échantillon d'une écume d'algues bleu-vert (catégorie 2b) prélevé dans la baie située au sud du lac. L'écume échantillonnée présentait une superficie très limitée, jugée **non significative**, de 0,12 m².		
Cyanobactéries :	Totales : **500 000-2 000 000 cellules/ml** À potentiel toxique : **500 000-2 000 000 cellules/ml**	
Cyanotoxines :	Microcystine-LR (toxicité équivalente) : 29 **µg/l**	non détectée ☐
	Anatoxine-a : **µg/l**	non détectée ☒

Station : CAR-F		**Type de prélèvement :** Tube 0-1m
Observations visuelles Échantillon d'une colonne d'eau d'une hauteur de 1 mètre prélevé dans une fleur d'eau de catégorie 1, secteur est du lac. La fleur d'eau est représentative de **l'état général du lac**.		
Cyanobactéries :	Totales : 2000-5000 **cellules/ml** À potentiel toxique : 2000-5000 **cellules/ml**	
Cyanotoxines :	Microcystine-LR (toxicité équivalente) : 0,14 **µg/l**	non détectée ☐
	Anatoxine-a : **µg/l**	non détectée ☒

Ministère du Développement durable, de l'Environnement et des Parcs
Québec

Interprétation des résultats d'analyses

☐	*Autre phénomène (autres types d'algues, pollen, etc.)* *Observations :*
☐	***Cote A :*** *Les résultats d'analyse des échantillons prélevés dans le plan d'eau ont démontré que la densité de cyanobactéries totales[1] était inférieure à 20 000 cellules/ml. Une densité aussi faible n'est pas considérée comme une fleur d'eau.* *Cette situation ne requiert pas une intervention de santé publique.* *Suivi visuel volontaire effectué par :* *souhaité (volontaires recherchés)* ☐
☒	***Cote B :*** *Les résultats d'analyse ont confirmé la présence de cyanobactéries totales[1] dans les échantillons prélevés dans le plan d'eau à une densité supérieure à 20 000 cellules/ml. Il s'agissait donc d'une fleur d'eau de cyanobactéries.* *Cette situation ne requiert pas une intervention de santé publique.* *Suivi visuel volontaire effectué par :* *souhaité (volontaires recherchés)* ☒
☐	***Cote C :*** *Les résultats d'analyse des échantillons prélevés dans le plan d'eau ont confirmé que la densité de cyanobactéries totales était supérieure à 20 000 cellules/ml. Il s'agissait donc d'une fleur d'eau de cyanobactéries. De plus, au moins un résultat en cyanotoxines dans la fleur d'eau, dépasse un des seuils visant à protéger l'usage le plus sensible (baignade ou eau potable) de votre plan d'eau* *Les informations sur la localisation, l'étendue de la fleur d'eau ainsi que les résultats d'analyses ont été transmis à la DSP. À la suite d'une évaluation de l'ensemble de la situation, la DSP informera la municipalité de sa décision et des mesures particulières à prendre, s'il y a lieu.* *Suivi visuel volontaire effectué par :* *souhaité (volontaires recherchés)* ☐
Prochaine visite (s'il y a lieu) :	

Actions à prendre par le destinataire

- Retourner, à l'expéditeur du mémo d'information, un **message <u>non automatisé</u>** confirmant la réception du mémo N° **05**
- Assurer si possible un **suivi visuel** de ce plan d'eau et effectuer un nouveau signalement au MDDEP si l'étendue ou l'intensité de la fleur d'eau s'accroit de façon importante. Nous informer s'il y a lieu d'un nouveau partenaire pour le suivi visuel.

<u>Actions supplémentaires pour les cotes B et C</u>

- ***Les recommandations générales en présence d'une fleur d'eau s'appliquent en tout temps. Ces recommandations se trouvent à l'adresse suivante :***
  http://www.msss.gouv.qc.ca/sujets/santepub/environnement/index.php?algues_bleu-vert
- Aviser le coordonnateur des mesures d'urgence ainsi que l'opérateur de la station de traitement de la présence de fleur d'eau de cyanobactéries dans le plan d'eau si celui-ci est utilisé comme source d'approvisionnement en eau potable
- Informer les exploitants de plages organisées localisées sur les rives du plan d'eau

Pour protéger un plan d'eau, prévenir ou réduire l'eutrophisation comme le développement d'une fleur d'eau de cyanobactéries, nous vous invitons à appliquer différentes mesures à l'échelle du bassin versant telles que protéger les rives et réduire les apports en phosphore.

Informations supplémentaires sur les algues bleu-vert et la protection des plans d'eau

Consulter le Portail national de l'information gouvernementale :
http://www.alguesbleuvert.gouv.qc.ca/fr/index.asp

Direction régionale du MDDEP : Personne à contacter : Isabelle Dorion	Tél. : 450 433-2220 poste 280
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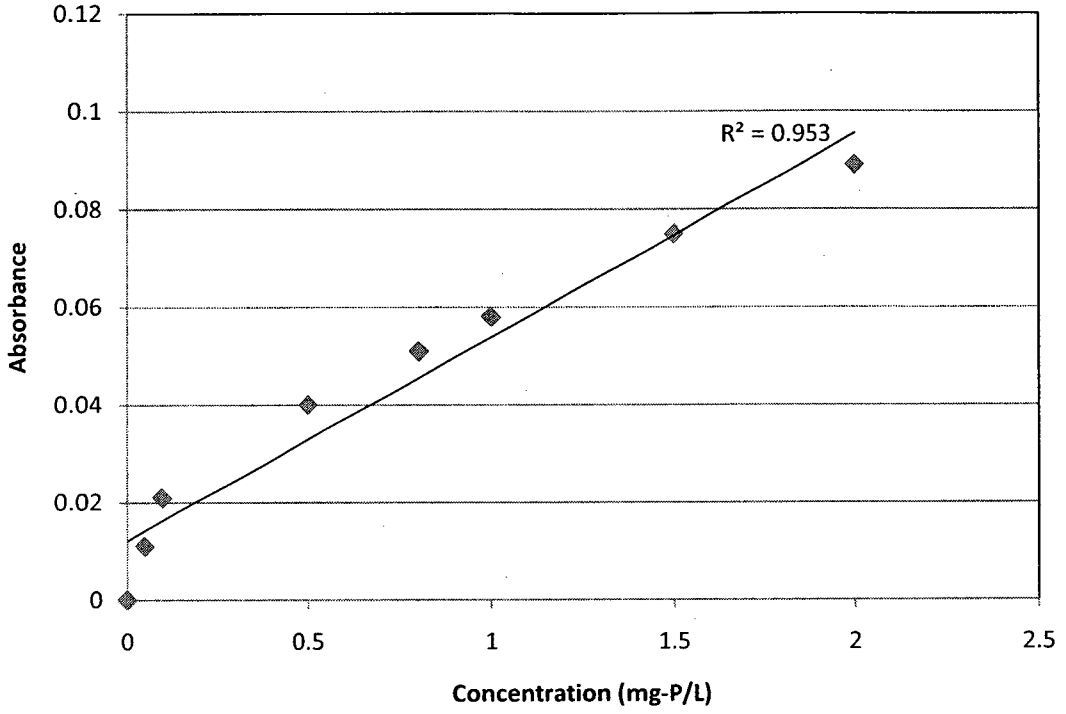
[1] **Cyanobactéries totales:** Ensemble des genres dominants de cyanobactéries présents dans l'échantillon. Les cyanobactéries totales regroupent donc les genres susceptibles de produire des toxines et les autres cyanobactéries.

Appendix C

Calibration curve obtained for TP analysis



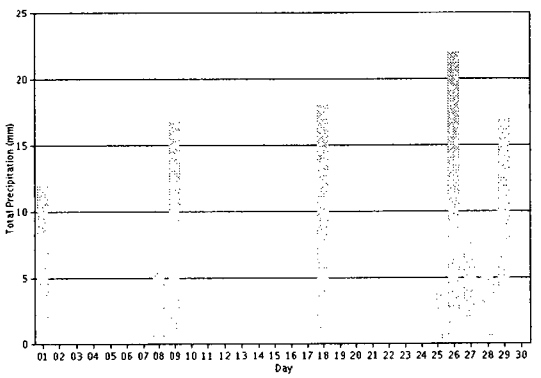
Appendix D

Precipitation data for Lake Caron during filtration tests: summer and fall 2009. The data was obtained from St. Jerome, Quebec weather station located close to St. Anne des lacs [Source: National Climate Data and Information Archive (www.climate.Weather office.gc.ca)].

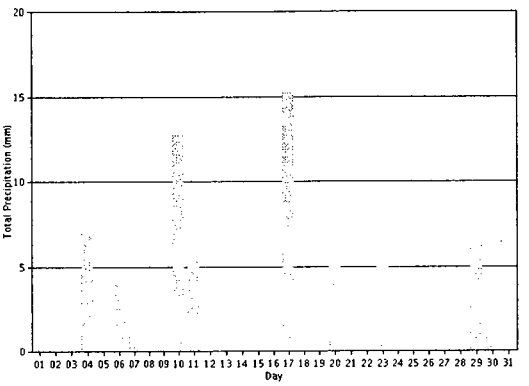
ST JEROME
QUEBEC

Latitude: 45° 48.000' N Longitude: 74° 3.000' W Elevation: 169.50 m
Climate ID: 7037400 WMO ID: TC ID:

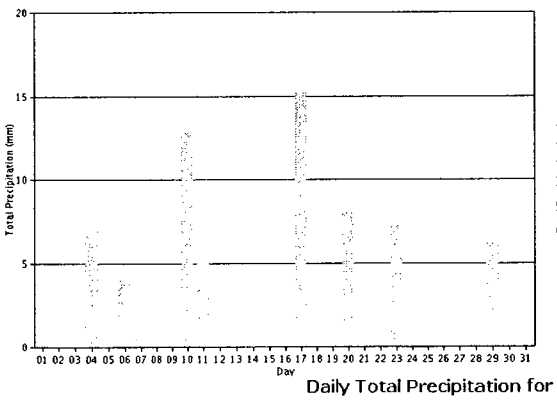
Daily Total Precipitation for June 2009



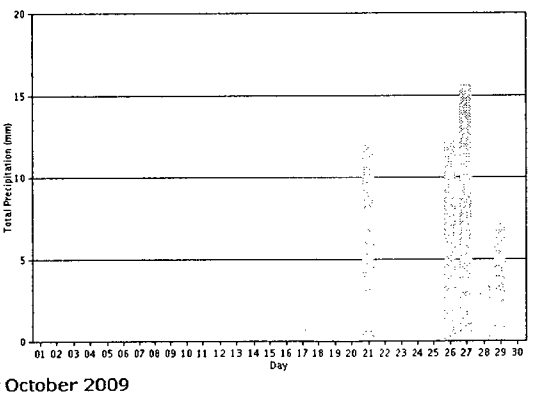
Daily Total Precipitation for August 2009



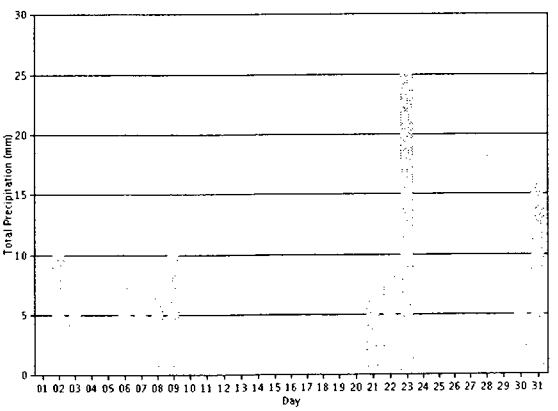
Daily Total Precipitation for August 2009



Daily Total Precipitation for September 2009



Daily Total Precipitation for October 2009

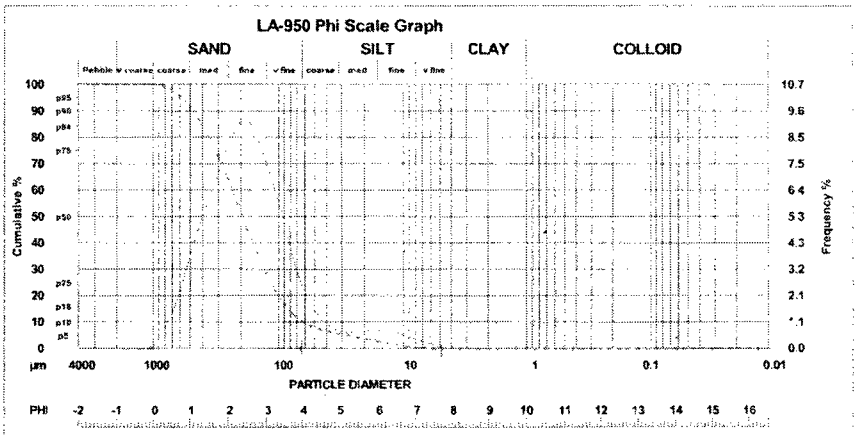


Appendix E

Particle size distribution for Station 6

HORIBA Laser Scattering Particle Size Distribution Analyzer LA-950

Sample Name	: Theju	Median Size	: 192.53275(μm)
ID#	: 200909011524845	Mean Size	: 234.42574(μm)
Data Name	: Aug. 312009 Lake Caron #3	Variance	: 28747(μm²)
Transmittance(R)	: 97.9(%)	Std.Dev.	: 169.5500(μm)
Transmittance(B)	: 93.0(%)	Mode Size	: 213.2914(μm)
Circulation Speed	: 5	Span	: OFF
Agitation Speed	: 2	Geo.Mean Size	: 173.2944(μm)
Ultra Sonic	: OFF	Geo.Variance	: 1.4007(μm²)
Form of Distribution	: Auto	Skewness	: 1.3284
Distribution Base	: Volume	Kurtosis	: 4.9838
Material	: Lake water	Diameter on Cumulative %	: (1)5.000 (%)- 27.2643(μm)
Source	: Misc		: (9)90.00 (%)- 470.3881(μm)
Sample Number	:		
Test or Assay. Number	: 0001		
Refractive Index (R)	: Theju[Quartz(1.450 - 0.000i),Water(1.333)]		
Refractive Index (B)	: Theju[Quartz(1.450 - 0.000i),Water(1.333)]		



	Diameter	PHI	MILS	Microns	Frequency	Frequency	CUMULATIVE
F PEBBLE	5	-2.00	157.48	4000.00	0.00	0.00	100.00
	6	-1.75	132.42	3363.59	0.00		100.00
	7	-1.50	111.36	2828.43	0.00		100.00
	8	-1.25	93.64	2378.41	0.00		100.00
FINE PEBBLE	10	-1.00	78.74	2000.00	0.00	0.00	100.00
	12	-0.75	66.21	1681.79	0.00		100.00
	14	-0.50	55.68	1414.21	0.00		100.00
	16	-0.25	46.82	1189.21	0.00		100.00
V CRS SAND	18	0.00	39.37	1000.00	0.06	0.06	99.94
	20	0.25	33.11	840.90	0.66		99.28
	25	0.50	27.84	707.11	1.37		97.92
	30	0.75	23.41	594.60	2.41		95.51
CRS SAND	35	1.00	19.69	500.00	3.85	8.29	91.66
	40	1.25	16.55	420.45	5.13		86.53
	45	1.50	13.92	353.55	5.28		81.25
	50	1.75	11.70	297.30	7.36		73.88
MED SAND	60	2.00	9.84	250.00	9.55	27.53	64.33
	70	2.25	8.28	210.22	9.42		54.91
	80	2.50	6.96	176.78	9.67		45.24
	100	2.75	5.85	148.65	9.03		35.21
FINE SAND	120	3.00	4.92	125.00	7.84	35.06	26.17
	140	3.25	4.14	105.11	5.56		21.61
	170	3.50	3.48	88.39	5.32		16.00
	200	3.75	2.93	74.33	3.71		10.79
V FINE SAND	230	4.00	2.46	62.50	2.59	18.18	7.20
	270	4.25	2.07	52.56	1.81		4.39
	325	4.50	1.74	44.19	1.24		2.15
	400	4.75	1.46	37.15	0.90		1.25
CRS SILT	450	5.00	1.23	31.25	0.73	4.62	0.52
	500	5.25	1.03	26.28	0.66		0.00
	635	5.50	0.87	22.10	0.67		4.19
		5.75	0.73	18.58	0.72		3.47
MED SILT		6.00	0.62	15.63	0.76	2.80	2.71
		6.25	0.52	13.12	0.79		1.96
		6.50	0.43	11.05	0.65		1.32
		6.75	0.37	9.29	0.52		0.80
FINE SILT		7.00	0.31	7.81	0.40	2.31	0.40
		7.25	0.26	6.57	0.27		0.13
		7.50	0.22	5.52	0.13		0.00

	Diameter	PHI	MILS	Microns	Frequency	Frequency	CUMULATIVE
	7.75	0.18	4.65	0.00			0.00
V FINE SILT	8.00	0.15	3.91	0.00	0.40		0.00
	8.25	0.13	3.28	0.00			0.00
	8.50	0.11	2.76	0.00			0.00
	8.75	0.09	2.32	0.00			0.00
	9.00	0.08	1.95	0.00			0.00
	9.25	0.06	1.64	0.00			0.00
	9.50	0.05	1.38	0.00			0.00
	9.75	0.05	1.16	0.00			0.00
CLAY	10.00	0.04	0.98	0.00	0.00		0.00
	10.25	0.03	0.82	0.00			0.00
	10.50	0.03	0.69	0.00			0.00
	10.75	0.02	0.58	0.00			0.00
	11.00	0.02	0.49	0.00			0.00
	11.25	0.02	0.41	0.00			0.00
	11.50	0.01	0.35	0.00			0.00
	11.75	0.01	0.29	0.00			0.00
	12.00	0.01	0.24	0.00			0.00
	12.25	0.01	0.21	0.00			0.00
	12.50	0.01	0.17	0.00			0.00
	12.75	0.01	0.15	0.00			0.00
	13.00	0.00	0.12	0.00			0.00
	13.25	0.00	0.10	0.00			0.00
	13.50	0.00	0.09	0.00			0.00
	13.75	0.00	0.07	0.00			0.00
	14.00	0.00	0.06	0.00			0.00
	14.25	0.00	0.05	0.00			0.00
	14.50	0.00	0.04	0.00			0.00
	14.75	0.00	0.04	0.00			0.00
	15.00	0.00	0.03	0.00			0.00
	15.25	0.00	0.03	0.00			0.00
	15.50	0.00	0.02	0.00			0.00
	15.75	0.00	0.02	0.00			0.00
	16.00	0.00	0.02	0.00			0.00
	16.25	0.00	0.01	0.00			0.00
COLLOID	16.50	0.00	0.01	0.00	0.00		0.00

1 / 1

Appendix F

Based on the filtration results obtained from GTX – 250 (filter 7), the following calculations were done to find the time and number of units required to treat the entire lake water.

Average suspended solids concentration in lake = 12.32 mg/ L.

Average total phosphorus concentration in lake = 0.084 mg/ L.

Average removal rate for SS = 6.3mg/m^2.sec ;

Average removal rate for TP = 0.0183mg/m^2.sec

$$\text{Removal rate} = \left[\frac{\text{the total amount of filtered water} \times \text{removal of SS concentration}}{\text{filter area}}\right]$$

Volume of lake = 50,200 m^3

The amount of SS present in lake: 618535 g; The amount of TP present in lake: 4213g

$$\text{Time required for treating entire lake} = \left[\frac{\text{Estimated amount of SS in lake}}{\text{Removal rate obtained}}\right]$$

For removing SS at this rate, it requires about 2 units and geotextile area of 2m^2. However, this set up may not be feasible for reducing phosphorus concentration because of the weather conditions (lake water freezes completely by late November). Therefore considering the available time frame (8-9 months) and also to have a good long term result, 3 units and geotextile area of 4m^2 is selected to treat the contaminants in the lake.

Appendix G

Cyanobacteria report from CEAEQ

Centre d'expertise en analyse environnementale
Québec

Certificat d'analyse

Direction de l'analyse et des études de la qualité du milieu
2700 rue Einstein
Québec (Québec)
G1P 3W8

Client: Thejashree Ramalingaiah
300-3404 avenue Prudhomme
Montréal (Québec) H4A 3H5

Nom de projet: Surface water in-situ filtration
Responsable: Thejashree Ramalingaiah
Téléphone: 514-746-0992
Code projet client:

Date de réception: 29 octobre 2009
Numéro de dossier: Q025205
Bon de commande:
Code projet CEAEQ: 2685

Numéro de l'échantillon: Q025205-01

Préleveur: Ramalingaiah Thejashree
Description de l'échantillon: Sample 1
Description de prélèvement:
Point de prélèvement:
Nature de l'échantillon: eau naturelle de surface

Date de prélèvement: 28 octobre 2009

Dépistage cyanobactéries: genre/classe abondance

Méthode: --
Date d'analyse: 11 novembre 2009

	Résultat	Unité	LDM
Genres à potentiel toxique			
Coelosphaerium	1 000 - 2 000	Cellules/ml	
Microcystis	1 000 - 2 000	Cellules/ml	
Planktothrix	1 - 1 000	Cellules/ml	
Total (1)	2 000 - 5 000	Cellules/ml	
Autres genres			
Aphanothece	1 - 1 000	Cellules/ml	
Cyanodictyon	1 - 1 000	Cellules/ml	
Planktolyngbya	1 - 1 000	Cellules/ml	
Total (2)	1 000 - 2 000	Cellules/ml	
Total	2 000 - 5 000	Cellules/ml	

Remarque(s)

Niveau: Paramètre

No Éch.	
Q025205-01	Dépistage cyanobactéries: genre/classe abondance

Remarque
L'échantillon contient aussi beaucoup de débris, ainsi que des cryptophycées et des chrysophycées.

Centre d'expertise en analyse environnementale
Québec

Direction de l'analyse et des études de la qualité du milieu
2700 rue Einstein
Québec (Québec)
G1P 3W8

Certificat d'analyse

Client: Thejashree Ramalingaiah
300-3404 avenue Prudhomme
Montréal (Québec) H4A 3H5

Nom de projet: Surface water in-situ filtration
Responsable: Thejashree Ramalingaiah
Téléphone: 514-746-0992
Code projet client:

Date de réception: 29 octobre 2009
Numéro de dossier: Q025205
Bon de commande:
Code projet CEAEQ: 2685

Numéro de l'échantillon: Q025205-02

Préleveur: Ramalingaiah Thejashree
Description de l'échantillon: Sample 2
Description de prélèvement:
Point de prélèvement:
Nature de l'échantillon: eau naturelle de surface

Date de prélèvement: 28 octobre 2009

Dépistage cyanobactéries: genre/classe abondance

Méthode: --
Date d'analyse: 11 novembre 2009

	Résultat	Unité	LDM
Genres à potentiel toxique			
Coelosphaerium	1 - 1 000	Cellules/ml	
Microcystis	1 000 - 2 000	Cellules/ml	
Planktothrix	1 - 1 000	Cellules/ml	
Total (1)	2 000 - 5 000	Cellules/ml	
Autres genres			
Aphanothece	1 - 1 000	Cellules/ml	
Cyanodictyon	1 - 1 000	Cellules/ml	
Planktolyngbya	1 - 1 000	Cellules/ml	
Total (2)	1 000 - 2 000	Cellules/ml	
Total	2 000 - 5 000	Cellules/ml	

Remarque(s)

Niveau: Paramètre

No Éch.	
Q025205-02	Dépistage cyanobactéries: genre/classe abondance

Remarque

L'échantillon contient aussi beaucoup de débris, ainsi que des cryptophycées et des chrysophycées.