



Filtration of contaminated suspended solids for the treatment of surface water

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ABSTRACT

As few technologies exist worldwide for the treatment of contaminated surface water, a new approach is currently under development consisting of an in situ water treatment system based on a floating filtration process for adsorbed contaminants such as heavy metals. Laboratory filtration tests were performed for the removal of contaminated suspended solids (SS) from surface water. SS, chemical oxygen demand (COD), and organic carbon (OC) were monitored. Of the four filters (two non-woven geotextiles, a woven geotextile and a sand filter) evaluated, filter 1 (a non-woven geotextile) was the most effective for removal % of the total suspended solids. The results demonstrated excellent efficiency by filter No. 1, for reducing turbidity by 93–98%, as well as SS by up to 98.9% and COD by 65–71% for three sites with initial turbidities of 70, 20, and 120 NTU, respectively. The level of heavy metal removal was 98.9% due the heavy metal content of the suspended solids (60 mg kg⁻¹ of Cu, 90 mg kg⁻¹ of Ni, 130 mg kg⁻¹ of Zn, 200 mg kg⁻¹ of Cr, and 80 mg kg⁻¹ of Pb). The development of this technology could potentially protect the public and aquatic plants and animals from dangerous contaminants such as heavy metals adsorbed onto the suspended solids.

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1. Introduction

Heavy metal contamination is a common, important, and growing problem around the world. Pollution from industrial discharges can produce high levels of suspended solids that can subsequently contaminate sediments within the surface water systems. For example, it was reported by Windom et al. (1991) that an average of approximately 40%, 62%, 80% and 92%, of the total amounts of Cu, Cd, Zn and Pb are carried by suspended solids in US east coast rivers. Nutrients and organic contaminants also partition to suspended particles, which can have a significant effect on the transport and fate of contaminants in water systems. The particles eventually settle and become sediments, affecting benthic organisms. As these organisms are located at the lower end of aquatic food chain, their contamination could subsequently affect the whole food chain due to bioaccumulation.

Suspended solids accumulate toxic components that will reach the bottom of the water. Phytoplankton and bacteria can live or adhere on to suspended solids. Therefore, the removal of suspended solids is essential for the clarity of the water and the reduction in chemical oxygen demand (COD). In addition to the high specific surface area of suspended and colloidal particles, heavy metals adhere to these particles in high concentrations (Yong et al., 2006). Contaminated sediments also pose risks to small organisms such

as crustaceans and insect larvae that live within these sediments and near the interface of the water and sediments.

A new approach, in development in Japan (Fukue et al., 2004), consists of using barges or other floating devices with filters to treat the polluted water. In this manner, the treatment is restricted to the contaminated water area and the system can be easily moved to any area where the treatment is required, and is thus potentially inexpensive. A silt curtain can be used to separate the area to be cleaned from the surrounding area. In Kasaoka Bay, the technology was capable of reducing the concentration of suspended solids from 25 mg L⁻¹ to 2 mg L⁻¹ using sand filtration (Fukue et al., 2004). The major disadvantage, however, of the sand filters is that during filtration of water of high turbidity, the filters will clog frequently and thus require longer filtration periods and extensive cleaning. This can substantially increase operational costs. Therefore, other filter materials need to be evaluated.

Geotextiles are man-made materials that are mostly used for soil improvement (LaGrega et al., 2001). The application of geotextiles as filtration media in surface water remediation is limited. Geotextiles are permeable textiles which are typically used for agricultural purposes (separation, reinforcement and drainage), and they are in two forms: (a) woven and (b) non-woven (LaGrega et al., 2001; Koerner, 2005). Non-woven geotextiles are felt-like materials which are formed by a random placement of threads and do not have any visible thread pattern (Koerner, 2005). Geotextiles have been used along shorelines to reduce the introduction of suspended material through erosion or shoreline construction

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projects for example, or in leachate collection systems. They can also be used in canals and channels that are downstream from dredging operations, such as for the dewatering of sediments in geotubes (Moo-Young and Tucker, 2002) and other geotextile containers in one- (Kutay and Aydilek, 2004) and two-layer systems (Kutay and Aydilek, 2005). Porosities are typically in the order of 90% and thus the rate of blocking should be decreased substantially, reducing operational costs. Although recently, Korkut et al. (2006) have investigated the use of geotextiles in wastewater as baffles for biomass hosts and Yaman et al. (2006) investigated geotextiles as biofilters. In this study, non-woven geotextiles were used as filtration media in a filtration column to determine the capability of using this kind of product for removal of suspended solids in surface water.

Three different types of filters of different hydraulic permeability were compared to sand filtration which had been previously used in the floating vessel tests. Use of the geotextiles would facilitate the operation of an in situ filtration. The objective of the work was to evaluate the filtration efficiency of three types of geotextiles, to compare them with sand filtration for removal of suspended solids from surface water and to establish the design parameters. To accomplish this, laboratory experiments using a floating filter and water recirculation were conducted. River samples were used as surface water and three fabric filters and a sand filter were compared. Reduction of turbidity, chemical oxygen demand (COD) and heavy metals were determined. The ultimate goal of the work is to develop an in situ water treatment system for the rehabilitation of contaminated surface waters such as rivers, lakes and ponds.

2. Materials and methods

2.1. River water sampling

Water samples at various points close to the shore along the St. Lawrence River in Montreal, Canada were taken by a bucket near the surface, particularly in the suburban areas of Lachine and Dorval to determine the range of actual turbidity values of the river. The turbidity of the samples was determined immediately with a portable turbidity meter and the temperature was measured. A LaMotte 2020 e/l portable turbidity meter (Cole-Parmer) with a detection limit of 0.05 NTU was used to measure sample turbidity on site after collection. Bottles were shaken thoroughly after filling once, emptied and then refilled for an immediate turbidity measurement. After each measurement, the turbidimeter sample cells were washed with distilled water. Water samples were conserved at 4 °C prior to experimentation.

2.2. Sediment sample characterization

Sediments were obtained from a harbor near the Montreal, Quebec, Canada area and were used as suspended solids for the

experiment as the water quality was good for most of the period when testing was performed. Due to the small grain size of the sediments (mainly less than 0.075 mm) grain-size analysis of the sediments was performed in Japan using the laser diffraction method of Furukawa et al. (2001). It was determined that 42.5% was sand, 27.2% was silt and 27.2% was clay according to ASTM method B822-97. A temperature of 750 °C was used to determine the ignition loss of the sediment solids (designated as organic content (OC)) according to the standard of the Japanese Geotechnical Society (2000). This was found to be 4.0%. The analyses of the metal contents of the sediments are indicated in Table 1 and were performed by inductively coupled plasma spectrometry (ICP). The analyses of some metals—i.e., iron (Fe), lead (Pb), copper (Cu), zinc (Zn), and manganese (Mn)—were carried out using inductively coupled plasma (ICP) atomic emission spectrometry after digestion with HNO₃, HF and HClO₄. As some metals appeared to be present at relatively high concentrations, a cross-check was made using atomic-absorption analysis. This technique was also used to measure the concentrations of elements such as cadmium (Cd). A Niton X-ray fluorescence spectrometer (XRF) XLP700 was also used to determine metal content of the solids on the filter for heavy metal retention during filtration.

Selective sequential extraction tests were performed using the method of Yong et al. (1993). Each fraction was collected and the concentrations of heavy metals in each fraction were determined by atomic-absorption spectrophotometry. Samples were washed with distilled water to prepare them for the next step. The amounts of copper, lead, zinc, chromium and nickel from each of the extractants were then calculated and represented as the % of the total for each metal in the sediment. The results of the total metal and the sequential analysis are shown in Table 1.

2.3. Laboratory filtration setup and filters

Filtration tests were performed in a plastic tank from Nalge Company with a 51 cm height, an inside diameter of 34 cm and a capacity of 46.5 L. The filtration column (made of plexiglass) was 7.9 cm in diameter and 43.5 m in height. Fig. 1 shows the filtration tank and column. Three different fabric filters of 7.9 cm in diameter were evaluated one at a time: filter 1 (black), filter 2 (gray) and filter 3 (white). Filter 1 was a non-woven geotextile supplied by Asahi-Kasei Geotech Co. Ltd. Trademark: AK-100. The gray non-woven filter (#2) was supplied by Aoki Marine Corp. Ltd. The other was a white woven fabric filter (#3). The filters were characterized for hydraulic conductivity using the constant head method (ASTM methods, 2432-D and 2434-D). Other parameters are shown in Table 2. A constant total head difference (8.5 cm) was applied to the filters and the sand specimen with specific area of 5.72 cm². The permeability experiment for each filter was repeated three times and the average coefficient of permeability for the filters and sand was calculated.

Table 1
Characterization of the sediment.

Element	Content (mg/kg)	CCME ISQG ^a for fresh water sediment	Selective sequential extraction, results shown as % of metal associated with each fraction compared to the total metal content					
			Soluble (%)	Exchang. ^c (%)	Carbonate (%)	Oxide (%)	Organic (%)	Residual (%)
Cu	60	35.7	21.4	5.4	5.4	10.7	32.1	25.1
Zn	130	123	1.7	2.4	14.7	35.3	16.8	29.2
Ni	90	NA ^b	<0.4	38.9	61.1	<0.6	<0.6	<0.7
Cr	200	37.3	<0.3	4.3	0.5	25.6	22.3	47.3
Pb	80	35	<1.2	28.6	14.3	28.6	<1.7	28.6
Total	560							

^a ISQG – interim sediment quality guideline.

^b NA – not available.

^c exchang. – denotes exchangeable.

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