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Using a geotextile with flocculated filter backwash water and its impact on aluminium concentrations

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ABSTRACT

The use of geotextiles (i.e. geotextile tubes) in wastewater treatment applications is ever increasing. This paper examines the potential of using a geotextile to improve upon the treatment of aluminium present in a filter backwash water that is generated from a water treatment plant in Halifax, Canada. A field investigation to ascertain the distribution of aluminium in the filter backwash water treatment process is provided and compared to regulatory guidelines at the environmental compliance point. It is shown that aluminium is undergoing incomplete treatment at various times throughout the year. To examine a potential corrective action, the results of bench scale studies are presented in which cationic additives (i.e. CaO, MgO, and Fe_3O_4) are combined with a polymer to remove aluminium from solution and flocculate particulate matter from the filter backwash water. A geotextile is utilized to retain particulate matter generated from this process. It is shown that the combined use of the cationic additive with polymer can successfully reduce aluminium concentrations in the filter backwash water and that filtration via a geotextile can retain the aluminium particulate in the filter backwash water to levels close to regulatory requirements. Further optimization with the flocculation process is recommended prior to pilot testing.

1. Introduction

Geotextile tubes, which consist of geotextiles sewn together to form hollow longitudinal tubes, have become common in engineering practice (Lawson, 2008). The use of geotextiles to dewater sludges and contaminated sediments is well documented in the literature (e.g. Fowler et al., 1994; Fowler et al., 1996; Gaffney et al., 1999; Yee et al., 2012; Bourgès-Gastaud et al., 2014). Aydilek and Edil (2002, 2003), Kutay and Aydilek (2004) and Guimarães et al. (2014) serve as examples of research performed to examine the potential for high water content wastewater treatment sludge to be filtered and subsequently dewatered with geotextile tubes. Satyamurthy and Bhatia (2009), Khachan et al. (2014); Guo et al. (2015) have all examined different methods of improving the dewatering efficiency for geotextile tubes. The focus of past geotextile tube studies has been related to the dewatering aspect of the sediment or sludge. A few studies (e.g. Rupakheti and Bhatia, 2017; Bhatia, 2017; Koerner et al., 2016; Rupakheti et al., 2016; Mori et al., 2002) have discussed water quality aspects related to geotube dewatering. Few studies have examined the use of flocculation combined with a geotextile as a treatment process for improving water quality.

The J.D. Kline Water Treatment Plant (JDKWTP) in Halifax, Nova Scotia, Canada is the main water treatment facility for Halifax Regional Municipality. Filter backwash wastewater (FBWW) aluminium levels have created regulatory challenges in the current treatment process used in the plant. The overall objective of this paper is to examine how geotextiles could play a role in the reduction of aluminium discharge concentrations in the FBWW at the plant. This work presents a proof of concept for a potential new geotextile application in which particulate and dissolved aluminium in the FBWW are removed via flocculation and subsequent retention by a geotextile. To present this proof of concept, the paper first describes the study site and field testing performed to assess the distribution of aluminium in the FBWW treatment system for the plant. Secondly, the results of bench scale testing are presented in which the ability of a geotextile to aid in the retention of aluminium from the FBWW of this plant is assessed; commercially available cationic additives (i.e. CaO, MgO, and Fe_3O_4) and a polymer are examined as a treatment phase to reduce particulate and dissolved aluminium in the FBWW followed by retention of the particulate matter by the geotextile.

2. Background information related to the study area: J.D. Kline Water Treatment Plant

The J.D. Kline Water Treatment Plant (JDKWTP) is a direct dual media filtration plant, currently operating at an average daily

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production of approximately 84 ML/day (Stoddart and Gagnon, 2015). Pockwock Lake serves as the source water for the plant and its water is characterized by low pH, alkalinity and turbidity. Treatment of this source water prior to distribution involves first pumping raw water to the plant, screening and then sending this water to a series of premix tanks. The first premix tank is for pH adjustment (~pH 10); followed by potassium permanganate addition (to oxidize iron and manganese) and a third premix tank for carbon dioxide addition (to ~ pH 5.5) and coagulant addition (aluminium sulphate at 8 mg/L). A polymer (Magnafloc LT20) is added during cooler temperatures, as a coagulant, to increase floc strength. After flocculation, the water is sent through eight dual media filters consisting of sand and anthracite. The filtered water is then subjected to addition of chlorine (disinfection), zinc/ortho phosphate (corrosion control), sodium hydroxide (pH adjustment to 7.4) and hydrofluosilic acid (preventing tooth decay).

The dual media filtration process at the plant is designed to retain particulate matter prior to disinfection. As the retention process occurs under constant flow of water, a reduction of hydraulic conductivity (i.e. clogging) of the filter beds occurs over time, accompanied by an increase in turbidity of the filtered water. To rectify this reduction in filter performance, the filters are routinely drained and 700,000 L of filtered water (i.e. before chlorine, zinc/ortho phosphate, sodium hydroxide, and hydrofluosilic acid addition) is then pumped from the base of the filter beds to fluidize the dual media filters and remove particulate matter from within the beds. After this process, the dual media filters regain their original hydraulic conductivity and can function as designed. This 700,000 L of water and accompanying solid particles used to "unclog" the filters is referred to as filter backwash water (FBWW) in this paper. This FBWW is sent via gravity flow to two engineered clay lined lagoons (capacity of 14,000 m^3) where sedimentation of particulate matter takes place. The outlets for both lagoons are overflow weirs; the size of the openings of which can be adjusted. The overflow from the two lagoons combines at an outlet chamber and discharges into a natural wetland, through a 1 m diameter concrete pipe. As shown in Fig. 1, the natural wetlands have a 1.5 km stream running through Hamilton Pond which subsequently discharges into Little Pockwock Lake. Little Pockwock Lake is downstream of Pockwock Lake; a controlled dam separates them. Where the wetlands discharge into Little Pockwock Lake at the edge of Halifax Water's property, the discharge criteria has been implemented (i.e. the "compliance point") by Nova Scotia Environment, the provincial regulator. At the compliance point, the FBWW discharge shall meet the following criteria: total suspended solids (TSS) must be below 25 mg/L; chlorine residual must be below 0.002 mg/L; pH must be between 6.5 and 9; total aluminium must be below 184 μg/L; and; discharge must be nontoxic to aquatic life.

To gain a better understanding of the occurrence of aluminium throughout the FBWW treatment process at JDKWTP, flow monitoring, tracer studies and water sampling were performed. All data were collected to provide insight into possible causes of the shortcomings of treatment of the FBWW with respect to aluminium.

The volumetric flow rate of water being discharged from the lagoon and the wetland was determined with the use of HOBO® U20 water level loggers (Onset® Computer Corporation, Bourne, Massachusetts, United States) and a 625DF2N digital pygmy meter (Gurley Precision Instruments, Troy, New York, United States). Two data level loggers were used; one at the lagoon discharge and the other at the wetland discharge. The third data logger was used to record barometric pressure. Readings were recorded every ten minutes. The pygmy meter was used to determine velocity and calculate the flow rate using the cross-sectional area of the flow channel. A rating curve for the inlet and outlet of the wetlands was created using the flow rates at a range of depths.

Flow monitoring over a period of one year captured the cycles of FBWW discharge to the lagoons. Typically results showed that with each nightly backwash, there was a 95% increase in the flow into the wetland from a normal base flow of about 0.3 L/s to a maximum of 7 L/s which quickly began to taper off within ten minutes. This suggests that the lagoons are not providing flow equalization before discharging into the wetlands. The wetland effluent flow saw a similar diurnal flow; however, the surge was dampened greatly. The flow increased by 20% from the average minimum of 240 L/s to 300 L/s. There was a three to five hour delay between the peak discharge into the wetlands and the peak discharge out of the wetlands. The drastic difference in flow volumes and the relatively short delay in between the peak flows at the inlet and outlet of the wetlands suggests that any treatment of aluminium occurring may be from dilution.

To gain an understanding of the reasons behind the observed flows, the hydraulic retention times throughout the FBWW treatment process were calculated from two rhodamine dye tracer studies. One tracer test was performed in July 2013 in which rhodamine dye (500-mL of rhodamine diluted in 23-L of water from the third flocculation tank) was injected at the gatehouse from a manhole that provides access to the influent pipe of the south lagoon. A two-filter backwash of 1400 m^3 was used. A second tracer test was performed in November 2012 for the wetland, starting where the lagoons discharge into the wetlands. The rhodamine dye concentration was continuously monitored where the wetlands discharged into Little Pockwock Lake at the compliance point. The study was conducted in-sync with a three-filter backwash that produced a volume of 2000 m^3 of backwash water. For the lagoon tracer study, the pink colour of the rhodamine could be seen at the overflow weir of the outlet within 25 min of the backwash pumps turning on. The mean retention time of the first backwash was calculated as 3 h and 50 min. Throughout the lagoons, there was clear short-circuiting around the perimeter of the lagoon. The rhodamine movement through the natural wetlands highlighted the very direct route from the lagoon discharge through the center of Hamilton Pond and discharging at the compliance point at Little Pockwock Lake. The mean retention time of the wetlands was calculated to be 12 h and 51 min. The relatively short retention time for the wetlands can be attributed to a sudden surge of FBWW and a very distinct channel running directly to Little Pockwock Lake. The lagoon discharge is not being contained for a sufficient time period in the wetlands or in Hamilton Pond.

The influence of this FBWW flow through the treatment system on aluminium concentrations was assessed via water sampling and water quality testing. FBWW water was sampled at three points along the FBWW treatment site. The three sample sites included the FBWW flowing into the lagoons, the lagoon discharge and the wetland discharge. In this paper the results for aluminium, pH, and TSS are reported. The lagoon discharge and wetland discharge were sampled during low flow conditions to represent a more typical discharge. Water quality results from field sampling are documented in Table 1. The results shown in Table 1 represent samples taken over the period between 2012 and 2013. The pH of the water discharging into Little Pockwock Lake fell just below the lower limit of the Canadian Water Quality Guidelines (CWQG) of 6.5. However, the pH of the water in this area is typically low; Pockwock Lake water averages a pH of 5.8 (Halifax Water, 2015). It was noted that on average, the dissolved aluminium concentration did not change within the lagoons. This is reasonable as the lagoons generally provide settlement of particulate matter. However, the dissolved aluminium increased throughout the wetlands, which is counter to the customary treatment method in a natural wetland that involves plant uptake of dissolved constituents such as aluminium (Kadlec and Wallace, 2009). It is also inconsistent with the pH of ~6.4 within the wetland, which is the range at which aluminium usually precipitates in water. This increase in dissolved aluminium in the wetland may be caused by anaerobic conditions. During sampling, odor indicative of anaerobic conditions was noted, however, more studies would be required to confirm this hypothesis.

Based on these field observations, it is apparent that the current treatment process for the FBWW is not performing as desired in terms of removing aluminium prior to discharge. To reduce aluminium concentrations in the FBWW prior to discharge, a simple addition to the treatment train was examined in the laboratory; namely the use of

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