Metal fate during geotextile dewatering of a contaminated sediment

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ABSTRACT

The use of geotextiles in sludge dewatering applications has become a popular approach for many engineering projects. For contaminated sediments, the water quality of the resulting effluent is important to quantify, as it affects decisions on secondary treatment of effluent from dewatering. The purpose of this paper is to discuss a bench scale study performed for a large-scale remediation project in Nova Scotia, Canada in which geotextile tube dewatering is one of the options for dewatering the contaminated, fine-grained sediment prior to containment. Selected metal concentrations in the sediment are elevated relative to guidelines. The purpose of this paper is to examine metal concentrations in geotextile filtration effluent during gravity dewatering tests at the laboratory scale. The sampling program of the contaminated sediment is briefly described as well as the results of various physical and chemical characterization tests performed on the sediment. The results of rapid dewatering tests performed with the sediment conditioned with additives to induce flocculation and increase grain size is presented. Characteristics of the resulting filtrate (metals and particle concentrations) are presented in the paper with a focus on the primary elevated metals known to be present in the sediment (Cu, Pb, and Zn). The distribution of these metals in the filtrate in terms of total versus dissolved concentrations is also presented and compared with particle counts in the filtrate to better understand the mobility of these metals during geotextile dewatering.
Keywords: geotextile, dewatering, filtrate, contaminated sediments, metal

1. INTRODUCTION

The use of geotextiles for the dewatering and containment of dredged materials, such as industrial waste can be found throughout the literature (e.g. Fowler et al. 1997; Bhatia 2004; Stephens et al. 2011). Although there is a significant amount of work in the literature related to dewatering with geotextile bags/tubes, most of the research has related to the influence of factors such as water content, solids retention, the pore size of the geotextile, flow and volume rates, etc., on the efficiency of the dewatering system (e.g. Muthukumaran & Ilamparuthi 2006; Mastin et al. 2008; Satyamurthy & Bhatia 2009). However, research regarding metal concentration and migration during geotextile filtration dewatering is limited (e.g. Lassabatere et al. 2004; Rupakheti & Bhatia 2017). Changes to the particle size of the sediment via conditioning through the addition of chemical additives has been shown to improve the performance with respect to filtration when using geotextile filters (Maurer & Bhatia 2012).

The objective of this study was to identify an optimal dosage of chemical additives for dewatering of a metal contaminated sediment. The bench scale testing conducted during this study will provide an insight into how varying levels of conditioning agents can impact the particle size and metal fate, and support the hypothesis that metal concentrations in dredged sediments can be reduced during a remediation which implements this dewatering technique. Specifically, this study was conducted to assess the filtration potential with respect to metal migration of a woven polypropylene geotextile fabric. To asses the capability of the technique, an anthropogenically influenced sediment, extracted from an industrial wastewater stabilization lagoon known to contain elevated concentrations of heavy metals, was subject to a suite of bench scale dewatering tests. The level of metal concentrations in the filtrate from these bench scale dewatering tests (i.e. Cu, Pb, Zn), which are known to experience variations in solubility under changing environmental conditions (Hermann & Neumann-Mahlkau 1985), were considered during this study.

2. MATERIALS AND METHODS

2.1 Contaminated Sediment

The planning for an active remediation project in Nova Scotia Canada involves investigating the dewatering of a contaminated sediment prior to ultimate disposal. The nature of this project provided the basis for further examination of metal fate during dewatering of contaminated sediments. The sediment examined for this study was an anthropogenically influenced material sampled from an industrial wastewater treatment facility (WWTF) in Nova Scotia, Canada, known colloquially as Boat Harbour. The site is slated for closure and subsequent remediation, commencing in January 2020. The sediment under examination was collected from a section of the facility known as the “stabilization lagoon” (Fig. 1). This lagoon, which operates as the final phase of a three-stage treatment process, was designed to allow for the

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precipitation of fine grained particulate matter over a residence period of between 20 to 30 days (Hoffmann et al. 2017), after which the treated material is released to the Northumberland Strait (Atlantic Ocean) through a hydraulic control structure (i.e., “Dam” in Fig 1). Over an operational lifespan of approximately 50 years, the low energy environment has resulted in the accumulation of a deposit totaling approximately 577,000 m^3 within the lagoon (GHD Limited 2018).

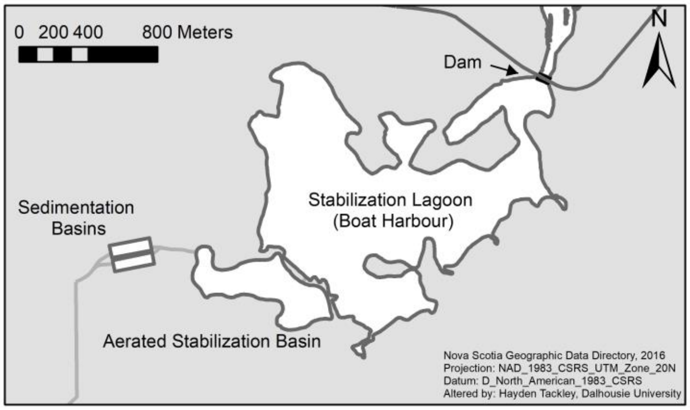

Figure 1: Boat Harbour WWTF sediment sampling site (2019)

The effluent which is treated by the WWTF originates from a nearby bleached kraft pulp and paper mill. Although not active now, other industrial wastewaters are also known to have been sent to this WWTF. Prior to entering the lagoon (stage 3), the effluent is subject to sedimentation (stage 1) and aeration (stage 2), in order to remove the majority of solid material present (GHD Limited 2018). The raw materials used in the pulping process (trees) contain various metal contaminants (Lewinsky 2007). The molecules tannin and lignin are examples of polymeric molecules and are major components of plant material. These materials are composed of long chains of phenols, which can adsorb metals which they encounter (Crist et al. 2002). These molecules may also contain metals from various sources, which have bioaccumulated over the lifetime of their parent tree (Sawidis et al. 1995), and may dissolve during the pulping and bleaching processes or remain bound to organics (such as lignin) that ultimately settle in the wastewater treatment facility. Although these metals appear in trace amounts in a pulp and paper effluent, they can accumulate via sedimentation over extended periods (Rahman et al. 2014). The removal of this anthropogenically influenced sediment is a primary consideration of the future remediation project on this site.

2.2 Geotextile Characteristics

The geotextile dewatering tubes (i.e. Geotubes®) which will be implemented at the Boat Harbour pilot remediation project are produced by the TenCate© Corporation. The tubes are fabricated from the geotextile fabric (GT500) consisting of woven polypropylene multifilament and monofilament yarns (Watts & Trainer 2010), and will henceforth be referred to as “the geotextile”. For this study, bench scale samples of the geotextile were implemented. The apparent opening size (AOS) of the geotextile is reported to be 430 µm with the thickness averaging 1.8 mm. The pore size distribution values for O_{50} and O_{95} are 80 µm and 195 µm, respectively (TenCate Corporation 2015).

2.3 Sediment Characteristics

The sediment which was used during the filtration efficiency analysis was sampled in bulk from the stabilization lagoon via an Ekman grab sampler. Approximately 20 L of sediment was extracted and sealed in an opaque bucket for transportation to Dalhousie University for analysis. Water required for dilution was sampled from the lagoon with care taken to not disturb the underlying sediment during collection.

Previous research by Hoffmann et al. (2017) has identified several heavy metals (Cr, Cd, Cu, Pb, Hg, As, Zn) at concentrations elevated above the background conditions within the deposit. A characterization of both physical and chemical properties of the sediment was conducted by Alimohammadi et al. (2019). The sediment was found to be fine grained, having an average particle diameter of 10 µm and was composed of approximately 30 % organic matter (by weight). The sediment is also known to be unconsolidated, having a moisture content (MC) of > 1000 %, and a solids content (SC) of 10 %, on average.

2.4 Sediment Modification

Tests involving various chemical additives and alterations to solid content through trial and error suggested the efficiency of filtration could be improved under the right chemical conditioning treatment. In order to promote the most efficient separation of solid material from the filtrate, a determination of the optimal dosage of additives was required.

The sediment was diluted to a solid content of between 0.98 and 1.1% with the addition of water taken from the BH WWTF active stabilization basin in order to create a slurry. This modified sediment was henceforth referred to as ‘1 % SC slurry’ and used as the base material for all subsequent testing. The 1% solid content was chosen based on a ‘worst case’ solids content for dredging operations, with similar solid contents being produced during the pilot phase of the remediation effort. The sediment was homogenized prior to the addition of the dilution water and weighed to ensure an accurate solid content percentage was consistently achieved.

2.5 Analytical Methods

In order to assess the effectiveness of the geotextile filtration technique with respect to improved filtrate quality, all analytical methods outlined below were conducted on both the untreated 1 % SC slurry, as well as the filtrate produced during the individual geotextile filtration tests.

2.5.1 Particle Size and Concentration

Grain size and particle concentration was determined using a Brightwell Technologies Inc. DPA-4100 flow microscope. The microscope had an effective measurement range of 2 µm – 300 µm and was able to measure material with particle concentrations of up to 175,000 particles per millilitre (Brightwell Technologies Inc. 2009). Slurry samples were diluted to 0.1% of the initial concentration using ASTM Type 1 water (ASTM International 1999). Filtrate samples were analysed without dilution. The procedure consisted of 1 mL of each sample being placed on the intake cell above the imaging field. Each sample was then pumped through the field at a rate of 0.22 mL min^{-1}. The apparatus was normalized prior to each trial by passing approximately 30 mL of ASTM Type 1 water through the imaging field. Particle concentration and particle size measurements were performed concurrently. The flow imaging device used proprietary software to determine particle size and concentration (number of particles per mL of sample).

2.5.2 Total Suspended Solids

The amount of total suspended solids (TSS) was measured using a HACH DR 5000 benchtop spectrophotometer. The analysis was completed in accordance with HACH specifications, wherein 10 mL of sample water was placed in a glass sampling jar and inserted into the machine for each trial. The spectrophotometer was calibrated before each use with a 10 mL sample of ASTM Type 1 water. The unit had an effective measurement range of 5 - 750 mg L-1 TSS (HACH Company 2014). Samples which yielded values in exceedance of the detection limit were diluted to 50, 10, or 1 percent (depending on exceedance) prior to re-testing.

2.5.3 Total Metal Concentration

Total and dissolved metal concentrations were determined for the filtrate produced during the bench scale experiment via ICP-MS, which was conducted in accordance with ASTM International (2016) method D5673 – 16. When considering total metal concentration, sample preparation was completed in accordance with APHA, AWWA, WFE (2005). 10 mL of filtrate was treated via the addition of 0.5 mL of concentrated NaOH. Samples were then placed in a block digester (Perkin Elmer SPB 50-24) and subjected to a temperature of 105 °C for 120 minutes. ASTM Type 1 water was then added to return the volume to 10 mL, before being refrigerated until analysis using a Thermo Scientific X Series 2 ICP-MS instrument. Total metal concentration in the unconditioned slurry was also conducted to identify a baseline for which to compare the filtrate against. The method utilized the same methodology as the filtrate, however, dilution to 0.1 % concentration (by volume) with ASTM Type 1 water was required prior to digestion.

2.5.4 Dissolved Metal Concentration

Dissolved metal concentrations in the filtrate were determined in accordance with APHA, AWWA, WFE (2005). Samples were filtered via syringe through a 45 µm Whatman cellulose nitrate membrane filter (25 mm diameter). Upon filtration of 10 mL of the desired sample, two drops of 0.2 M NaOH were added for stabilization before being refrigerated until analysis.

2.5.5 Zeta Potential

Zeta potential (ZP) was measured to identify the surface charge on particles present in the filtrate and diluted slurry. The analysis was completed using a Malvern Panalytical Zetasizer Nano ZS with samples prepared in accordance with APHA, AWWA, WFE (2005). The instrument, which was capable of measuring particles ranging from 3.8 nm – 100 nm in diameter, used electrophoretic light scattering to determine zeta potential, accurate to 0.12 um.cm/V.s (Malvern Instruments Ltd. 2019). 1.5 mL of filtrate was processed for each trial.

2.6 Chemical Additives

Analysis by Bishop Water Technologies (Renfrew, ON) determined that a two-step process would likely be required to efficiently promote flocculation in order to separate the water content from the solid material. A dual additive conditioning technique was implemented, as such techniques have been shown to produce significantly larger flocs when dealing with highly stable, fine-grained sediments (Gregory & Barany 2011). The two additives identified were a water-soluble cationic polymer (Solve 9244) and a cationic flocculating agent (Solve 7118). As recommended by the manufacturer, the additives were diluted from their initial concentration using ASTM Type 1 water to 0.5 % (by volume) for the polymer and 1 % for the flocculating agent.

2.7 Bench Scale Test Procedure

Filtration tests using the geotextile were completed to determine the optimal additive dosage which yielded the highest effluent quality with respect to metal reduction and filtration of solid particles. An initial visual test was conducted to observe the effect of 25 additive dosages of varying concentration on the 1 % SC slurry. For the initial trial, precisely 30 mL of 1% SC slurry was placed in a 50 mL sterile test tube. Both the polymer and the flocculating agent were added to the sample in sequence at each selected concentration, both individually or mixed prior to treatment. The tubes were then sealed and thoroughly homogenized allowing for the additives to activate and integrate with the particulate matter. Upon mixing, the samples were situated vertically in a holding tray, and the sediment (now coalesced as flocs) allowed to settle out of suspension. During the settling period, the duration required for sedimentation was monitored for each sample. Following 10 minutes of sedimentation, the clarity of the supernatant was observed visually. The rate of sedimentation and supernatant clarity were used as a superficial indication of the effectiveness of each dosage.

To identify the concentration of the additive dosage that yielded the highest filtrate quality (with respect to metal reduction), nine concentrations (Table 1), which consistently showed improvement in terms of floc size and supernatant clarity relative to the untreated slurry were selected for further analysis. A bench-scale rapid dewatering test (RDT) was conducted in accordance with industry specifications using the geotextile (TenCate Corporation n.d).

Table 1: Additive dosages selected for geotextile tests. Note samples 3 and 9 were conditioned with identical additives (9 combined prior to mixture with 1 % SC slurry).

Sample Number	Cationic Polymer		Flocculating Agent	
	% (diluted)	*ppm (undiluted polymer)*	*% (diluted)*	*ppm (undiluted flocculent)*
GT1	6.67	333	3.33	333
GT2	10.00	500	3.33	333
GT3	5.00	250	5.00	500
GT4	6.67	333	5.00	500
GT5	8.33	417	3.00	300
GT6	8.33	417	5.00	500
GT7	10.00	500	3.00	300
GT8	10.00	500	5.00	500
GT9	5.00	250	5.00	500
Untreated	0	0	0	0

The bench-scale RDT apparatus consisted of a 150 mm diameter circular piece of the geotextile, which was inserted into a 150 mm polypropylene funnel. The lower opening of the funnel was inserted in a 250 mL Erlenmeyer flask to allow for the collection of the filtrate generated during each test (Fig. 2). For each test, 200 mL of the 1 % SC slurry was prepared and homogenized using a Phipps and Bird PB 700 jar testing apparatus. The volume of the flocculating agent, which was equivalent in percentage to that used during each corresponding small scale (visual test) sample was then introduced to the slurry and mixed for 3 minutes at 300 rpm. The coinciding volume of the cationic polymer was then added to the sample. The combined polymer/slurry solution was mixed at 270 rpm for 1 minute to allow for thorough integration of the polymer with the slurry, in accordance with ASTM International (2019) method 2035. The jar tester was then slowed to 50 rpm to allow for flocculation to occur. The slurry-additive mixture (or untreated slurry for the control sample) was then poured in to the funnel, and the filtrate was allowed to drain through the geotextile.

During filtration, filtrate was collected in the Erlenmeyer flask, while the filter cake (solid fraction) was allowed to accumulate on the surface of the geotextile. For each trial, 50 mL of filtrate was removed from the flask immediately following an allotted drainage period of 600 seconds. Following the completion of each bench-scale RDT trial, analysis of the filtrate was completed using the analytical methods discussed in section 2. Analysis was done to determine the quality, and in turn, the effectiveness of the conditioning treatment with respect to metal reduction on the filtrate. Results from each dosage trial were compared in order to determine the optimal dosage which yielded the highest reduction potential.

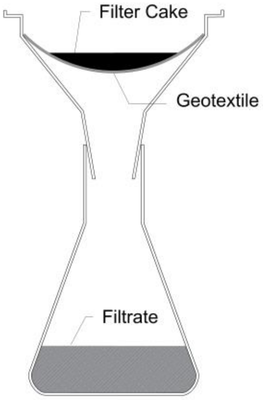

Figure 2: Bench-scale RDT apparatus

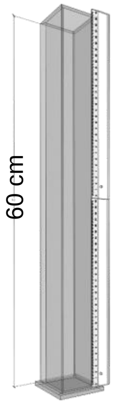

Figure 3: Sedimentation column for floc size analysis

2.8 Floc Size Measurement

The flocs which were produced during conditioning were found to be too large to be measured by the flow imaging technique implemented previously. Additionally, removal of the flocs from the saturated environment in which they formed resulted in deformation and particle diameters not consistent with ‘in situ’ (initial) size and shape. The flocs were found to have a high propensity to break apart or clump together upon disturbance and therefore, an alternative method of determining their size was required.

To determine the grain size of the flocs, a sedimentation column was constructed out of a 6.35 mm thick transparent acrylic sheet. The column was square in cross-section with each side measuring 50.8 mm (internal), with a height of 60 cm, and having a volume equal to approximately 1.5 L (Fig. 3). The column was placed in front of a white background to ensure high contrast between the translucent water/ supernatant and the relatively dark-coloured flocs.

Prior to floc size analysis, 1.2 L (80 % of the volume) of water was poured into the column. A 200 mL sample of 1 % slurry was conditioned with the optimal additive dosage via the jar testing procedure outlined in section 2.6. The treated sample was then poured into the column and the flocs were allowed to settle to the bottom. A digital camera was set up to record the flocs as they descended through the water column. The camera was equipped with a polarizing filter to eliminate reflective glare from the acrylic.

The images which captured the settling of the flocs were analyzed using the software ‘ImageJ,’ the capabilities of which with respect to particle size analysis have been discussed by Igathinathane et al. (2008). Prior to analysis, the images were processed to accentuate the contrast allowing the software to more accurately differentiate between individual flocs. The software analysis was able to produce a qualitative (with respect to the extent of the image field of view) determination of the grain size for all flocs which appeared in a given image. As this analysis was only meant to provide a qualitative idea of the grain size produced by the optimal additive dosage, each floc was assumed to be elliptical in shape. The test was repeated for six images for each of two trials, with consideration taken to choose images which contained various concentrations of flocs. The major and minor axis values were then averaged to yield an estimate of the floc size as it existed prior to filtration.

3. RESULTS AND DISCUSSION

3.1 Slurry Properties

A summary of the physical and chemical characteristics determined for the 1 % SC slurry can be seen in Table 2. The properties identified for this material were used as a baseline to compare the effectiveness of all subsequent dewatering and decontamination results with respect to filtrate quality in this report.

Table 2: 1 % SC slurry properties (used as a baseline comparison for all treated sediment).

1 % SC Slurry Properties		Metal Concentrations	(µg L^{-1})
Average Particle Size (µm)	*5.8*	Copper	*1178*
Particle Concentration (# mL^{-1})	*1.8x10^{8}*	Lead	*1385*
TSS (mg L^{-1})	*13,120*	Zinc	*15750*
Zeta Potential (mV)	*- 25*		

3.2 Trial Filtrate Characteristics

3.2.1 Physical Properties

When considering total suspended solids in the nine filtrate samples, values ranged from a low of 35 mg L^{-1} to a maximum of 193 mg L^{-1}. The results from the TSS test showed the most variability when compared to the other parameters measured (particle size and particle/metal concentrations). Dosages which corresponded to sample “Geotextile 1” (GT1) and GT3 consistently yielded the lowest levels of suspended solids (an average of 40 and 35.5 mg L^{-1} respectively), while all other trials produced concentrations which averaged greater than 50 mg L^{-1}.

Particle size remained relatively constant between 2.5 and 3.5 µm in the filtrate, with an average of 3.2 µm, slightly smaller than that determined for the untreated slurry (5.8 µm). Particle concentrations generally echoed TSS for each of the dosages, having average concentrations ranging between 4.1x10^{5} and 2.4x10^{6} particles per mL, with GT1 and GT3 again yielding the lowest average values.

3.2.2 Metal Concentrations

Total and dissolved metals which were measured in filtrate samples generated during optimal dosage identification trials are presented in Figure 4. Average total concentrations of copper existed between 6 and 12 µg L^{-1} of filtrate.

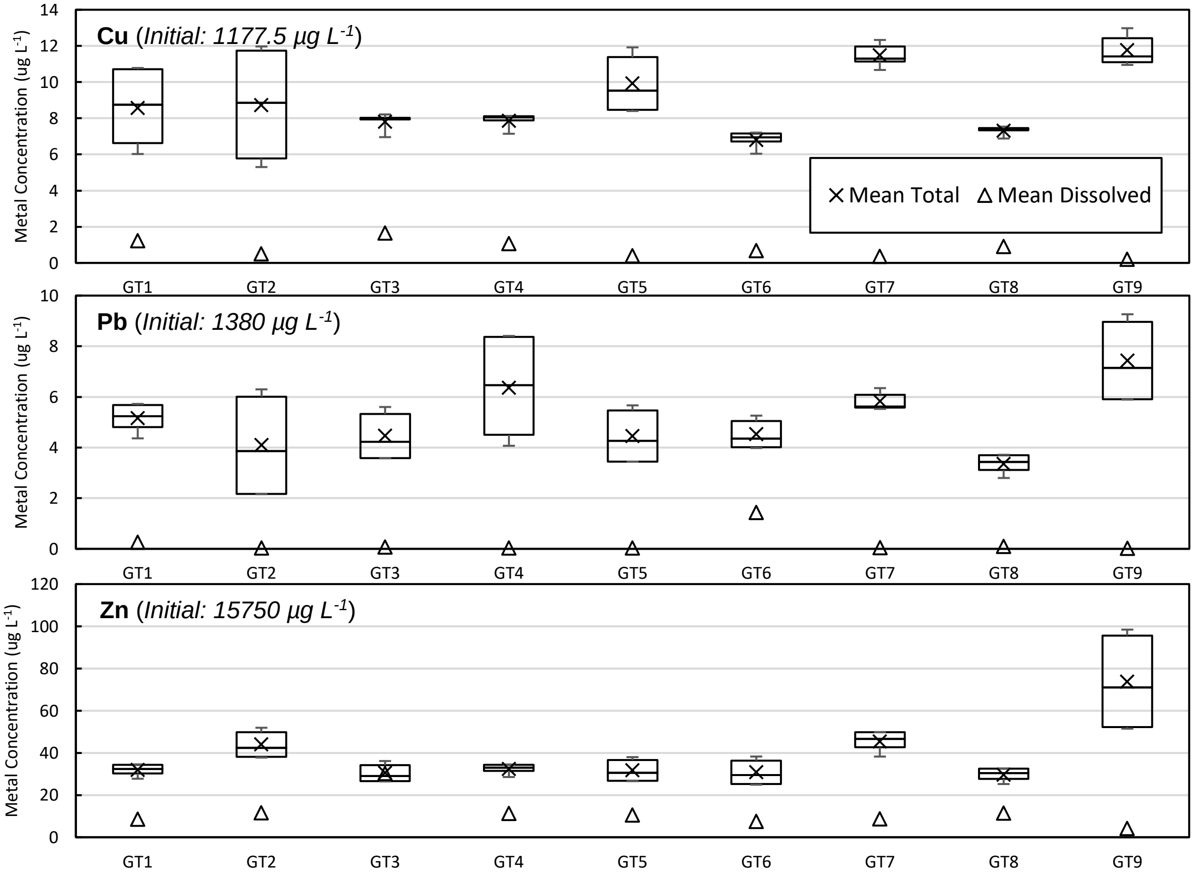

Figure 4: Metal concentrations in filtrate generated during the optimal dosage identification trials (statistical analysis of 3 repeated tests).

Total lead was present at a similar concentration, with averages ranging from 3 and 8 µg L^{-1}, while total zinc occurred between 20 and 80 µg L^{-1}. When comparing the dissolved concentrations to total concentrations, values for copper and lead were found to be on average 90 % and 95 % lower for all nine dosages respectively, ranging from a high of 1.6 µg L^{-1} to a low of 0.2 µg L^{-1} for copper and 1.4 µg L^{-1} to 0.0307 µg L^{-1} for lead. Dissolved zinc was generally consistent between dosages, occurring at concentrations of approximately 10 µg L^{-1} on average. This value typically equated to between 25 - 30 % of the total metal concentration; however, dissolved measurements approaching 100 % of the total zinc were recorded.

3.3 Identifying the Optimal Dosage

The optimal additive dosage was determined by comparing the results of the filtrate quality tests conducted on the individual filtrate samples (corresponding to the nine dosages). For all additive dosages considered, total metal concentration was reduced by over 99 % when compared to the initial sample. Of note was the performance of sample GT9, which contained an identical additive volume to that of sample GT3 (Table 1). GT9 performed below average in all tests (TSS, particle concentration, metal concentrations), and contained the highest concentration of all three total metals when compared to the other dosages. It is evident by this result that the two-stage conditioning process was vital to the effectiveness of the treatment.

Sample GT3 showed either average or above average results for all tests considered (TSS, particle concentration, metal concentrations). In addition to the performance with respect to filtrate quality, this dosage (GT3) required an amount equal to 5 % of the total volume of slurry for both the flocculating agent and the cationic polymer (made down to their respective dilutions), and therefore was easily repeatable. The volume of additive which corresponded to that applied to sample GT3 was therefore selected as the optimal dosage.

3.4 Properties of Optimal Dosage Treated Filtrate

The metal concentration reduction potential achieved by the optimal dosage conditioning is represented in Table 3. Following filtration, over 99 % of the solid material (as represented by TSS in the filtrate) was retained by the geotextile filter. Average metal concentrations are shown for both the initial untreated/unfiltered 1 % slurry, as well as the untreated/filtered control trial. Analysis of the filtrate collected from the untreated control sample confirmed no meaningful reduction in metal concentration could be achieved through geotextile filtration alone, without the implementation of the chemical conditioning treatment.

Table 3: Filtrate quality (TSS, particle concentration, & metal concentrations) of optimal dosage conditioned slurry (GT3).

	Particle Conc (# mL^{-1})	TSS (mg L^{-1})	Cu (µg L^{-1})	Pb (µg L^{-1})	Zn (µg L^{-1})
Untreated (Unfiltered)	1.8×10^8	13,120	1177.5	1385.0	15750
Untreated (Filtered)	---	---	1110.0	1360.0	14600
Total in Filtrate	4.5×10^5	35.5	7.8	4.5	30.4
Dissolved in Filtrate	---	---	1.7	0.1	30.3

The optimal dosage filtrate contained total metal concentrations averaging 7.8 µg L^{-1} of copper, 4.5 µg L^{-1} of lead, and 30.4 µg L^{-1} of zinc. Copper appeared in the dissolved fraction at an average equaling 21 % of the total concentration, while lead occurred at 2 % of the total concentration. The concentration of zinc present in the filtrate produced during the optimal dosage treatment was consistently found to be almost entirely in the dissolved fraction. The dissolved metal concentrations can likely be attributed to environmental factors within the filtrate, such as pH and oxidation reduction potential (Hermann & Neumann-Mahlkau 1985), however, such considerations are beyond the scope of this paper.

In addition to metal reduction in the filtrate, TSS was reduced from an initial 13,120 mg L^{-1} to an average of 36 mg L^{-1}, while particle concentration was reduced from 1.8×10^8 to approximately 4.5×10^5 particles per milliliter on average. The results generated via the bench scale test have shown the effectiveness of the contaminant reduction capability of the geotextile dewatering process for this particular contaminated sediment.

3.5 Effect of Optimal Dosage Treatment

3.5.1 Floc Growth and Sediment Retention

The stability of the 1 % SC slurry prior to conditioning can likely be attributed to the relatively high negative ZP (surface charge) which was found to be approximately - 25 mV. High surface charges on small particles such as these can cause a repulsion between particles (Maurer & Bhatia 2012, Lu & Gao 2010), which may have been preventing aggregation of the sediment. The addition of the cationic polymer (ZP ≥ + 80 mV) was thought to disrupt this stability and create a surface to which the negatively charged grains would more readily bind, and as a result, encourage flocculation (Betancur et al. 2009). Initial trials using only the cationic polymer resulted in little to no growth in particle diameter, with much of the fine-grained material remaining in suspension. The addition of the flocculating agent served to reduce the negative charge (bring ZP closer to zero mV), therefore destabilizing the system and encouraging the particulate matter to coalesce upon the introduction of the cationic polymer. The conditioning resulted in rapid floc growth and a material which was more readily able to precipitate out of suspension.

The floc size was determined using the method outlined in section 2.7. Average values were calculated for both major and minor axes, and were determined to be 960 µm and 610 µm respectively. The floc size measured using this technique represents growth by a factor of approximately 200 when compared to the untreated slurry (~6 µm).

Due to the fragile nature of the flocs, a great deal of fragmentation and reunification occurred during the preparation of samples used for floc size determination (this was also apparent in samples produced for the bench-scale analysis). As a result, floc size varied considerably between samples from the same trial and were inconsistent when considering duplicate trials. In addition to the disturbance generated during treatment, interaction with the geotextile and existing filter cake immediately transformed the free-floating particles into a more cohesive, uniform substance, lacking any individually discernible grains, and which was efficiently retained by the geotextile.

Particle size analysis of the flocculated material was conducted merely to gain insight into the effect of the additive treatment before filtration, rather than characterize a specific grain size. As a result of the variability identified during this test, the size of the grains discovered might be better thought of as a qualitative view. This average size was found to be larger than both the untreated particles, as well as the AOS of the geotextile as identified in section 2.1 (430 µm).

Based on the ImageJ floc size analysis technique discussed above, and the retention seen during experimentation with treatment via the optimal dosage as shown by the reduction of TSS in the filtrate, it is evident that a large enough average floc diameter was achieved to reduce the migration of sediment through the geotextile.

3.6 Contaminant Reduction

By implementing an effective conditioning dosage such as that identified during this study (and applied to sample GT3), it is possible to increase the particle diameter to a size which is more effectively filtered by the geotextile. As represented by total suspended solids and particle concentration in the filtrate, it has been shown that a greater than 99 % reduction in solid material can be achieved using this technique. Total metal concentrations were reduced in the filtrate when compared to the untreated slurry by a similar magnitude to the solid material for each of the three metal contaminants considered.

The reduction in both particle concentration and TSS measured in the filtrate and total metal concentrations suggests an apparent correlation exists between the metals and solid particulate. As mentioned, the metals in the sediment are thought to be associated with the dendritic material processed at the mill from which the effluent originated. Therefore, if a further reduction in the concentration of particulate matter in the filtrate can be achieved, either by an improved additive conditioning treatment (which promotes increased particle accretion), or further filtration induced by the development of a filter cake on the geotextile, it may be possible to further reduce the total metal concentration as well.

4. CONCLUSION AND RECCOMENDATIONS

This study was conducted to examine the filtration potential and efficiency of a geotextile fabric with respect to the migration of three select metals (Cu, Pb, and Zn) with known differences in solubility. Varying concentrations of additives were applied to a contaminated sediment to alter the particle size and in turn improve the efficiency of the filtration technique. Identification of the optimal additive dosage was made by implementing a bench-scale rapid dewatering test which yielded a filtrate used in for relative comparison to the untreated sample. Each of nine applied dosages were compared in order to identify an optimal dosage which produced the highest quality filtrate with respect to metal reduction.

By applying an optimal dosage of conditioning additives to the sediment it was possible to increase the particle size to a level which was more readily retained by the geotextile. As a result of the retention in the solid particulate matter, total metal concentrations measured in the filtrate for all three metals considered were reduced by over 99 % when compared to the initial concentrations identified in the raw material. Trace concentrations of each of the three metals were measured in the filtrate collected during all individual dosage trials, however when compared to the initial slurry only a small fraction was present in the dissolved fraction. This result confirms the hypothesis that metals (which behave similar to the three considered in this report) can be reduced in dredged sediments during a remediation implementing this technique. Further research which considers the association between the two constituents (metals and particulate) may help to further identify the rationale behind the retention properties of the geotextile, as well as identify any potential means of future contamination due to environmental changes which may effect metal solubility.

ACKNOWLEDGEMENTS

The authors would like to thank the organizations which contributed to the study; Bishop Water Technologies, Nova Scotia Lands Inc., and GHD Group, as well as Acadia University's Department of Earth and Environmental Science. Funding was provided by NS Lands Inc. and NSERC.

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