Stability of Treatment Sludge in Various Disposal Environments: A Multi-Year Leaching Study

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Abstract A multi-year project was undertaken to study the behaviour and environmental effects of various common treatment sludge disposal practices. The column leaching study examined the stability of actual sludge samples under various disposal scenarios to evaluate whether the sludge could prevent sulphide oxidation or provide an effective barrier to oxygen. The thirty plus column leaching study evaluated metal mobility from sludge samples collected from several Canadian mines sites under simulated disposal environments such as under subaqueous and subaerial conditions, mixed with tailings or disposed of as a cover over tailings. The leach columns were monitored for up to four years to determine if disposing sludge with tailings would impact on the overall stability of the waste (i.e. which waste disposal scenario is chemically more stable) and whether sludge would dissolve more readily when disposed of with tailings. The paper presents the results of this multi-year study including the leachate composition.

Key Words lime treatment, pond disposal, codisposal, sludge cover, subaqueous, subaerial, tailings

Introduction

A multi-year project was undertaken (Fiset et al. 2003) to study the leaching behaviour and the environmental effects of various sludge disposal options available at several operating/inactive mine sites. The objective of the project was to evaluate and investigate several disposal options for lime treatment sludges, including codisposal with tailings, layered disposal over tailings, and pond disposal. For a detailed discussion on sludge management options the reader is referred to Zinck (2005). The column leaching portion of this study examined the stability of sludge samples under various disposal scenarios with the aim to answer the following questions:

- Does sludge slow or prevent sulphide oxidation?
- Does sludge make an effective barrier to oxygen?
- Does the practice of disposing sludge with tailings impact on the overall stability of the waste?
- Does sludge dissolve more readily when disposed of with tailings?

A total of 36 leach columns were commissioned to evaluate metal mobility and sludge disposal under various conditions. Sludge samples from three sites (Geco, Brunswick and Heath Steele) and tailings samples from Geco and Gallen were used to simulate various types of disposal environments. After 54 weeks, 13 columns were decommissioned due to premature oxidation of the Geco tailings. The remaining 10 columns continued to be monitored while 13 new columns were commissioned in the spring of 2000 using Gallen Mine tailings and Brunswick fresh sludge. The new columns started on week 70 of the overall study and are identified as such in the data. The composition of the sludges tested can be found in Aubé and Zinck (1999).

Experimental

Plastic (Lexan) piping was used to construct the columns. The approximate size of the columns was 15 cm (ID) by 30 cm (height). Geotextile cloth was used at the bottom for support, above which was 2.5 cm of polypropylene beads, then 17.5 cm of material. The columns were equipped with a gas trap to prevent oxygen infiltration from the bottom.

The columns were charged with a fixed mass of sludge/tailings such that the appropriate bed height was 17.5 cm. The columns were leached once a week with 155 mL of synthetic rain to simulate ambient wet/dry cycles. This rate was based on the low permeability of the sludge, which is the limiting flow factor, sampling requirements, and an estimation of average rainfall and run-off amounts for the area. The tests were conducted for approximately 150 weeks to allow sufficient time for initiation of biological activity.

The leachant in these tests was synthetic rain water at pH 4.5 in a dilute matrix of sulphuric and nitric acid. Four additional columns (in duplicate) were leached with distilled water. A Consort multimeter C835 was used to measure pH, Eh, and Ec in a flow through cell. The columns were housed in a laboratory greenhouse equipped with a climate controller 6008 and humidity sensor. Details of the column leaching study can be found in Table 1.

In addition to the column leaching tests, full chemical, physical, mineralogical characterization was completed for all samples pre and post leaching. As well, batch leaching tests including TCLP and modified TCLP were completed. These results however are not presented in this paper.

Results and Discussion

Pond disposal

The column leaching study simulating sludge pond conditions showed that metal mobility was not a concern for the given leaching period. As long as the buffering capacity was available, metal mobility was minimal. However, the Heath Steele and the Brunswick sludge samples showed higher zinc mobility during the leaching study, but the pH remained neutral (Figure 1). In general, metal and sulphate concentrations decreased with time below regulated limits. The addition of a water cover over the sludge had a significant impact on the metal mobility. The Cd, Cu, Mg and Zn in the leachate were lower when a water cover was applied over the sludge as it provided buffering capacity possibly through the dissolution of calcite and gypsum present in the sludge. In addition, the presence of a water cover prevented sludge cracking and consequently provided better buffering capacity distribution to the system. Detailed mineralogy and chemical analyses conducted on the samples before and after column leaching revealed significant gypsum depletion in the sludge and a reduction in calcium and sulphate concentration in the solid phase.

***Table 1** Column leaching parameters*

Site	Column Name	Composition	Leachant			Test Conditions			Monitoring Conditions	
			Type	dosage (ml/wk)	contact time (hr)	Temp (degrees ©)	Humidity (%)	Sampling frequency	Length (wks)	Parameters pH,Eh,Ec
GECO	GUT	Geco unoxidized tailings in duplicate	synthetic acid rain	155	5	20-25	85-95	bi-weekly	54	√
	GOT	Geco oxidized tailings in duplicate	synthetic acid rain	155	5	20-25	85-95	bi-weekly	54	√
	GSTI	Geco sludge-tailings interface in triplicate (samples taken from the field).	synthetic acid rain	155	5	20-25	85-95	bi-weekly	54	√
	LFSUT	Layered fresh Geco sludge (2%) over unoxidized Geco tailings (98%) in triplicate.	synthetic acid rain	155	5	20-25	85-95	bi-weekly	54	√
	GCO	Geco codisposal scenario in triplicate. 2% Geco sludge mixed with 98% Geco Tailings	synthetic acid rain	155	5	20-25	85-95	bi-weekly	54	√
	GFS	Geco fresh sludge in duplicate.	synthetic acid rain	155	5	20-25	85-95	bi-weekly	160	√
Brunswick	BFSS	Brunswick fresh sludge in duplicate.	synthetic acid rain	155	5	20-25	85-95	bi-weekly	160	√
	BFSW	Brunswick fresh sludge in duplicate.	distilled water	155	5	20-25	85-95	bi-weekly	160	√
	NBFS	Newer Brunswick fresh sludge in duplicate.	synthetic acid rain	155	5	20-25	85-95	bi-weekly	100	√
	BSWC	Brunswick sludge with water cover in duplicate	distilled water	155	5	20-25	85-95	bi-weekly	100	√
Gallen	GAT	Gallen tailings in duplicate.	synthetic acid rain	155	5	20-25	85-95	bi-weekly	100	√
Heath Steele	HSFSS	Heath Steele fresh sludge in duplicate	synthetic acid rain	155	5	20-25	85-95	bi-weekly	160	√
	HSFSW	Heath Steele fresh sludge in duplicate	distilled water	155	5	20-25	85-95	bi-weekly	160	√
Gallen and Brunswick	BSOGT	2% Brunswick sludge layered over 98% Gallen tailings in triplicate.	synthetic acid rain	155	5	20-25	85-95	bi-weekly	100	√
	COD	Codisposal of 98% Gallen tailings and 2% Brunswick sludge in triplicate.	synthetic acid rain	155	5	20-25	85-95	bi-weekly	100	√
	BLK	Test control- 3 inches of sand	synthetic acid rain	155	5	20-25	85-95	bi-weekly	160	√

Sludge layer over tailings

Three scenarios were evaluated using a layer of sludge over tailings. Of these, two were commissioned in the laboratory and one was collected directly in the field. The Geco sludge over Geco tailings simulated a layer of sludge over partly oxidized tailings (LFSUT). For this scenario, the

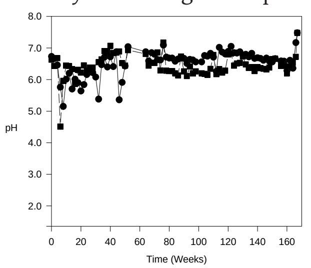

***Figure 1** pH profile versus time for Heath Steele sludge*

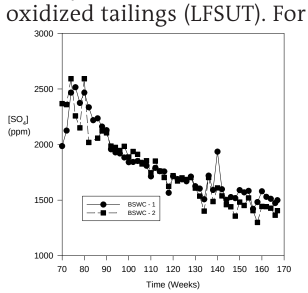

***Figure 2** Brunswick fresh with water cover, sulphate concentration versus time*

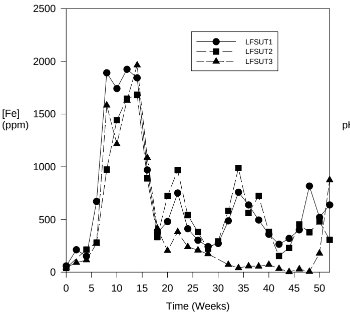

Figure 3 Geco sludge over Geco tailings (LFSUT), iron concentration versus time

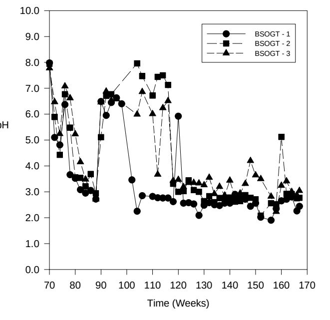

Figure 4 Brunswick sludge over unoxidized tailings (BSOGT), pH profile versus time

sludge layer minimized the amount of iron and sulphate leached, however the concentrations of iron (Figure 3), sulphate and zinc were significant (Zn ≈ 100 mg/L). After 52 weeks of leaching under this scenario the pH dropped by more than two units and the Eh increased by almost 300 mV.

The second disposal scenario commissioned in the laboratory, Brunswick sludge over unoxidized Gallen tailings (BSOGT), experienced significant zinc and iron leaching. The pH profile shows an initial multiple peak pattern probably due to thiosalts formation and followed by a marked drop in pH (from ≈ 8 to 2.5 during the leaching period, Figure 4). Compared to the Gallen tailings alone (control), the sludge layer did not appear to slow down the rate of tailings oxidation. Evidence of local oxidation was observed along the column walls as well as also in the center of the column. The column paste pH measured at various locations in the column varied between 3.9 and 5.6. The final series of columns (GSTI), which were assembled in the field and monitored in the laboratory, showed advanced oxidation and metal leaching from the onset (pH ≈ 2 and Eh 600—700 mV).

Sludge permeability plays a particularly important role in this type of disposal as the less permeable the material the less likely water and oxygen would contact the tailings, causing oxidation. The challenge is maintaining the sludge barrier integrity. Cracks which commonly occur in the sludge through desiccation provide for preferential channels for the leachant to travel through the sludge directly contacting the tailings.

From these scenarios, the sludge layer disposal option was not effective in stopping or significantly reducing the oxidation. The sludge layer did not act as a satisfactory barrier to oxygen and did not decrease to any degree the sulphide oxidation. Issues related to the application of layered sludge over tailings in the field are sludge cracking and preferential channelling. The sludge would need to be disposed in a way that the particles will not segregate and consequently remain saturated. Maintaining water in the sludge pore space will prevent sludge cracking and minimize tailings exposure to oxygen.

Codisposal of sludge with tailings

Two scenarios were evaluated mixing sludge and tailings. The first one consisted of 2% of Geco sludge mixed with 98% Geco tailings and the second scenario was a mixture of 2% of Brunswick sludge with 98% of Gallen tailings. In the first case (GCO), sludge mixed with tailings did not appear to slow or prevent oxidation. In fact, results were worse in this scenario than compared to the Geco tailings alone. Lower paste pH, higher Eh and higher metal loads (Figure 5) were measured for the GCO compared to the Geco tailings alone. In this scenario, the tailings were partly oxidized, which resulted in accelerated oxidation and sludge dissolution. These data suggest that the addition of 2% of sludge in partially-oxidized tailings cannot retard oxidation or prevent acid generation.

The second scenario was commissioned using fresh Gallen tailings and Brunswick sludge (COD). The degree of metal leaching from this scenario was much lower than that experienced by the GCO columns. However, high levels of zinc were leached (Figure 6) for this codisposal scenario and visible oxidation occurred at the column surface. After 97 weeks of leaching, there was a difference between the metal leachability of the COD and the Gallen tailings (GAT) columns. Less zinc

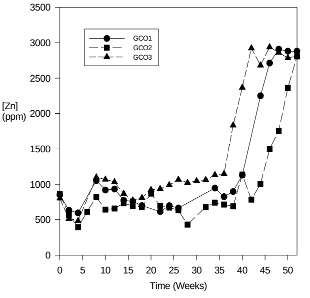

Figure 5 *Geco sludge mixed with Geco tailings (GCO), zinc concentration versus tim*

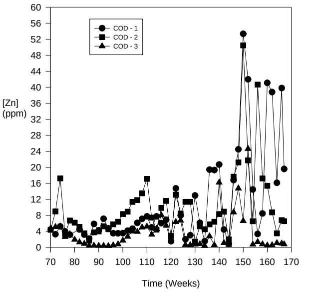

Figure 6 *Codisposal of Brunswick sludge with Gallen tailings (COD), zinc concentration versus time*

was leached from the COD scenario and similar amount of iron was leached compared to the control (GAT). The amount of sulphate leached from the COD columns was similar to the Brunswick fresh sludge column. Using fresh tailings, this scenario suggested that sludge mixed with tailings could only reduce the metal mobility in the short term. In the longer-term, a higher degree of oxidation is anticipated as full dissolution and alkaline depletion of the sludge may occur.

Conclusions

The column leaching study evaluated the performance of several sludge disposal options. In the columns simulating a sludge pond disposal scenario metal mobility was minimal and was not a concern during the leaching period examined. For pond disposal, as long as excess alkalinity remains in the sludge, metal mobility should be limited. For sludge samples having a higher propensity to leach metals, the addition of a water cover can significantly decrease the degree of metal mobility experienced, particularly for the zinc.

Three disposal scenarios were used to assess the practice of disposing sludge as a cover over tailings. Some evidence showed that the layer of sludge could in some scenarios minimize metal mobility, but the sludge layer disposed over tailings did not prevent or significantly slow oxidation. During the leaching study, the sludge layer did not act as a physical barrier due to sludge cracking and preferential channelling. In addition, in some cases disposal of sludge over tailings had a negative impact on the chemical stability of the tailings by promoting preferential pathways for the leachant to directly contact the tailings. The sludge layer did not provide enough alkalinity to minimize metal mobility.

Two codisposal scenarios of sludge mixed with tailings were evaluated. The addition of 2% sludge with tailings appeared to minimize metal mobility only for a short period of time. Results showed that the net alkalinity only offset acid generation and metal mobility in the short term. Once oxidation was established, the available alkalinity in the sludge was quickly depleted.

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