Delineation of metal sources in runoff from East Tailings Management Area (ETMA), Lynn Lake, Manitoba, Canada as a means to optimize remediation efforts

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Abstract Sources of metals were delineated and characterized in heterogeneous tailings of an inactive Cu-Ni mine near the Lynn Lake, Manitoba, Canada. Independent evidence obtained from: 1) analysis of surface-water chemistry and flows 2) extractions of soluble metals from the top 0.1 m of tailings, and 3) seasonal mass-balance calculations, together indicated that the area with fine tailings (slimes) is responsible for most of the metal loadings transported by surface runoff from the tailings to the Lynn River.

Key Words tailings, soluble metals, runoff, loadings

Introduction

During the operation of a Cu-Ni mine between 1953 and 1976, approximately 20 million tonnes of acid-generating tailings were produced and discharged within the East Tailings Management Area (ETMA), covering approximately 250 ha near the Town of Lynn Lake, Manitoba, Canada. Coarse "cycloned" tailings, which were deposited in proximal areas as a pile, contain more sulphides compared to the fine "slimes" settled in the distal areas. Current runoff from the ETMA is acidic (pH ≈ 4) and contains elevated concentrations of Al, Ni, Zn, Cu, Co, and Cd. Most of runoff from the ETMA flows eastwards from the Cyclone Pile through a system of ponds and then discharges to the Lynn River (Figure 1). Two-dimensional modeling of sulfide oxidation and metal release predicted that the cycloned tailings could generate more metals than the slimes in the future (Gunsinger et al. 2006). Groundwater under cyclone tailings found to be more contaminated than beneath the slimes (TetrES 2005). Therefore, the Cyclone Pile was considered as a major source of metals contaminating runoff from the ETMA. The major objectives of this study were to delineate metal sources within the ETMA and to quantify metal loadings coming from these sources in order to optimize a remediation strategy.

Methods

The sources of soluble metals were delineated and metal loadings were estimated using a combination of geochemical and hydrological methods. The ETMA sub-watershed units were delineated using "raindrop" analysis module in ArcGIS software with a Digital elevation model used as the input. The results of this analysis also helped to optimize sampling locations.

Surface water was collected from streams and pools during the snowmelt in May of 2008. Water samples were filtered through a 0.45-µm filter in the field. One aliquot from each location was acidified with ultra-pure HNO_3 to preserve metals, a second was left unpreserved for sulphate analysis. These aliquots were kept refrigerated (4°C) prior to analysis by a certified laboratory. Water flows along runoff pathways were calculated from velocities and average cross-sectional area of the stream. Velocities were estimated using stopwatch and floating tools with an estimated precision of 20—30%. Metal loadings along flowpaths were calculated by multiplying flows and concentrations.

Tailings were collected with a steel trowel to a depth of 10 cm in July of 2007 from the surface of ETMA. Tailings samples were frozen prior the extraction of soluble metals. Soluble metals were extracted using techniques recommended by MEND (MEND, 2000). One-hundred gram samples of dry tailings were then mixed with 400 ml of double-distilled water in a sterile and clean 500 ml plastic bottle and agitated for 24 hours. The sample was filtered through a 0.45 µm filter and handled the same as water samples.

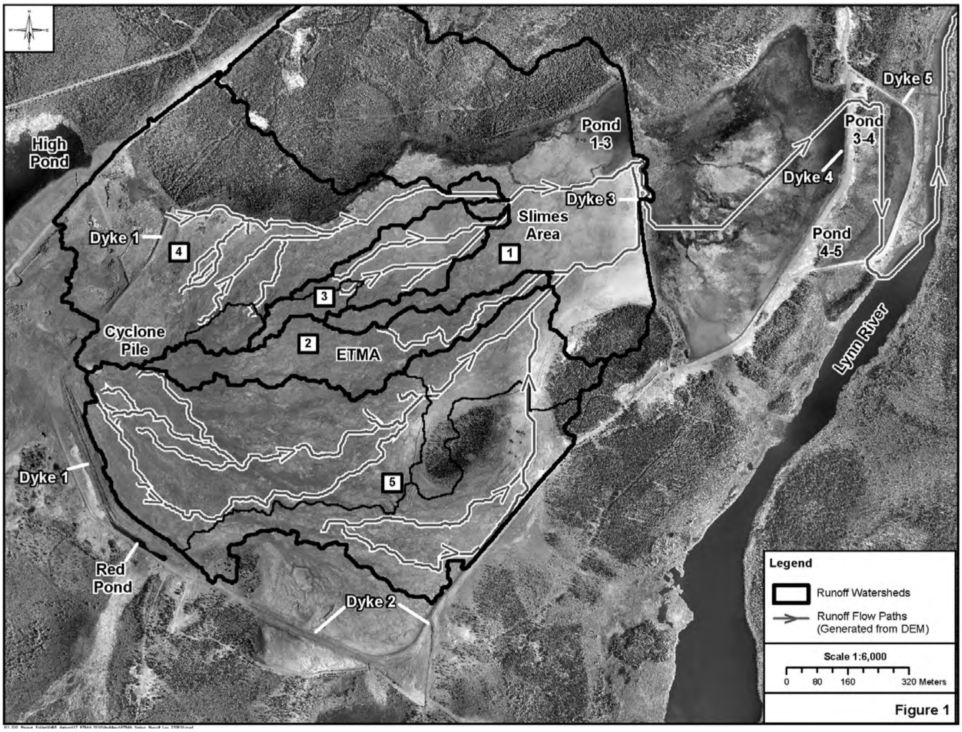

Figure 1 *Major watersheds of ETMA and flow directions and based on “raindrop” analysis of DEM*

To estimate quantities of soluble metals accumulated in the source prior to fall rains, two additional sets of samples were collected from the surface of slimes in the same locations on May 7th and July 3rd of 2008. Concentration of soluble metals were estimated using the protocol as described above.

The amount of soluble metals accumulated in slimes between May 7th and July 3rd was calculated by subtraction of the concentration in spring samples from the summer ones. The masses of accumulated metals were estimated using the following formula:

$$M = A \times h \times n \times C \times 10^{-6}; \text{ where}$$

M – mass in kg; A – area of slimes = 50000 m^2; h – depth of sampled tailings = 0.1 m; n – porosity = 1500 kg/m^3; C – an average or median concentration of accumulated metals in mg/kg; 10^{-6} – conversion factor from mg to kg (Table 1)

Table 1 *Comparison of metal masses accumulated from May 7th to July 3rd in 10 top cm of slimes with masses of annual metal discharged from Pond 4—5, kg*

	Calculation/ year	Al	Cd	Co	Cu	Mg	Ni	Zn	SO_4
Accumulation in slimes	Median	9700	1.4	290	1400	22800	9600	260	616000
	Average	31900	2.1	430	2600	36300	14800	940	761000
Pond 4-5 discharge	2005*	7600	0.58	110	510	11300	3700	290	196000
	2006	7400	0.44	100	370	12800	3400	200	190000
	2007	7800	0.74	210	640	20600	6700	350	314000

* incomplete record for flow (underestimated loadings)

Results and discussion

Water extractions from solid tailings indicated that the surface of the Cyclone Pile contained 10—100 times less soluble Ni, Cd, Co, Cu, and Zn the samples taken from the easterly slimes area (Figure 2). This observation agrees with a formation of temporary sulphate crusts on the slimes.

A comparison of the mass of soluble metals accumulated in the upper portion of the tailings with the annual metal discharge from ponds to the river showed that the slimes area could generate enough soluble metals to support the loadings associated with runoff from the ETMA (Table 1). Annual metal discharge ranges between years but even highest annual discharge (2007) is still lower than the lowest estimated mass of metals accumulated in the slimes for incomplete dry period, excepting Zn and Mg (Table 1). The comparison indicates that the slimes can generate sufficient mass of Al, Cd, Co, Mg, Ni and sulphate to provide 100% of the loadings in ETMA runoff with only a portion of soluble metals being flushed from the slimes area (Table 1). Conservative estimates show that some portion of Zn and Mg can be generated outside of slimes.

Surface streams occur within five major sub-watershed units of the ETMA (Figure 1). Analysis of the metal loadings in surface waters indicates that watershed 4 yields the most Zn (88—100%), Al (58—90%) and about half Cd (43—52%), Ni (34—49%) and sulphate (49 –58%) to the ponds. In this watershed unit, the most metal loadings, except for zinc, were generated along the streams eroding fine tailings. The zinc source is located in headwaters, which is likely fed by seepage of contaminated groundwater. In watershed units 1, 2, 3, and 5 most metal loadings were generated within the slimes.

Conclusions

The results of the study provided several independent lines of evidence indicating that the slimes were responsible for most of the metal loadings associated with ETMA runoff. High rates of metal release within the fine tailings could be due to high surface area compared to coarse cycloned tail-

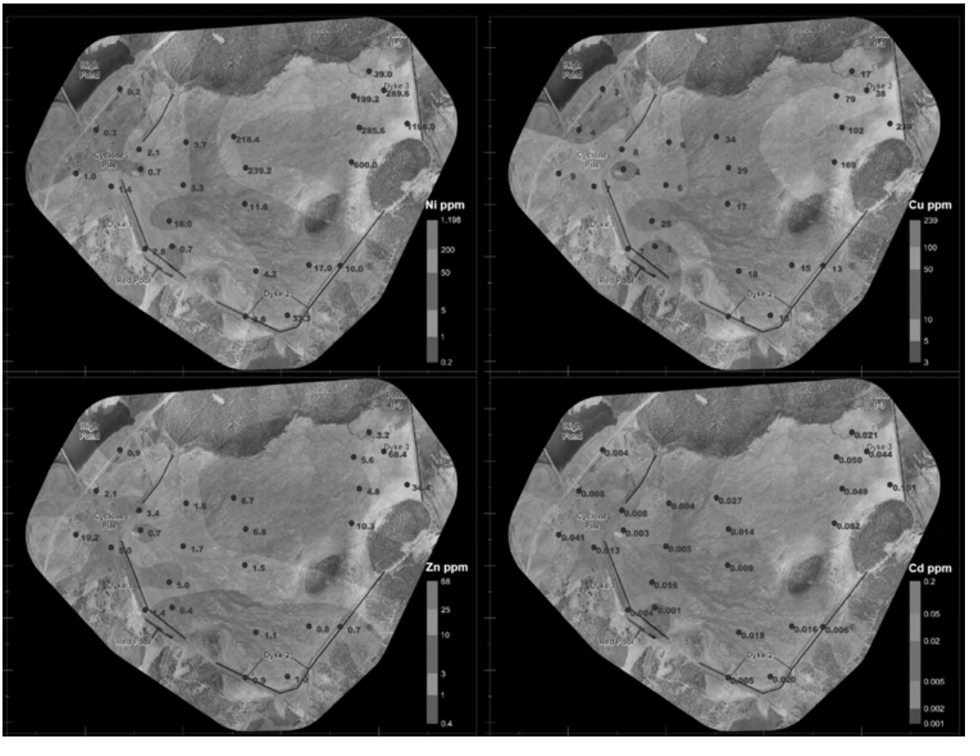

Figure 2 *Distribution of soluble metals on the surface of the tailings*

ings. Also loadings from the slimes could be originally sourced from other areas within the ETMA and evapoconcentrated in the slimes. In any case, to improve runoff quality, remedial actions should focus on current source of soluble metals – distal, rather than on proximal, areas of the ETMA.

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References

Gunsinger MR, Ptacek CJ. Blowes DW, Jambor JL. (2006). Evaluation of long-term sulfide oxidation processes within pyrrhotite-rich tailings, Lynn Lake, Manitoba. Journal of Contaminant Hydrology 83: 149—170

MEND 2000. MEND Manual Volume 3 – Prediction. GA. Tremblay and C.M. Hogan (Eds). MEND report 5.4.2c.

TetrES Consultants Inc. 2005. 2005 Activities, Farley Mine ETMA, Lynn Lake, MB. Unpublished Report to Viridian Inc. and Manitoba Mines Branch, Winnipeg.