

Diavik Waste Rock Project: Blasting Residuals in Waste Rock Piles

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Abstract

Mining generates and moves the highest volume of material in the world. At mine sites throughout the world, explosives are used to fragment rock into workable size fractions. Mine-water chemistry can be influenced by residual blasting agents used during mining. Ongoing monitoring of the water chemistry from three large-scale waste rock test piles, measuring 60 by 50 m in area and 15 m high, began in 2007 and the quality of water draining from this material is being studied. Blasting residuals comprised a large proportion of dissolved constituents in the pore water and effluent for the first three monitoring seasons. Variations in concentrations and the gradual rates of dissipation of blasting residuals provide an indication of the pile heterogeneity and the relative contribution of different flow paths. As temperatures within the piles increase with ambient temperature increases, larger proportions of the pile contribute to flow, and increased concentrations of blasting residuals are observed in waste rock effluent. Mass-balance calculations based on the ratios of SO_4 :Total-N can be used to estimate the relative contributions of sulfide oxidation within the piles and sulfate released when sulfur in the host rock is oxidized during blasting. These calculations can also provide an estimate of S mass released during the first flush of the piles. This research will aid in understanding the release of constituents caused by blasting and waste-rock hydrology.

Introduction

At mine sites throughout the world, explosives are used to fragment rock into workable size fractions. Ammonium nitrate mixed with fuel oil (ANFO) is the primary blasting agent used in metal and coal mining. Ammonium nitrate is hygroscopic, and with any increase in moisture content the explosive loses strength, potentially resulting in a failure to detonate releasing nitrate (NO_3^-) and a trace amount of ammonia (NH_3) and nitrite (NO_2^-) to pit water, pore water and effluent. Explosives are detonated with a boosting agent that contains perchlorate (ClO_4^-), which can release chloride (Cl^-) during detonation. Sulfate (SO_4^{2-}) can be released from sulfide mineral oxidation during blasting. These blasting agent residues and undetonated explosives present the opportunity to examine flow characteristics and geochemical processes within mine wastes.

Site Description

The Diavik diamond mine is located 300 km northeast of Yellowknife, NWT on a 20 km² island in Lac de Gras. Waste rock generated from the open pit and underground mine operation is stockpiled on site and at mine closure will consist of one 120 Mt waste rock stockpile. Waste rock at Diavik consists of granite and pegmatite containing irregular xenoliths of biotite schist. These host rocks are cut by intrusions of diabase. Diavik segregates waste rock into three categories, Type I rock, principally granite, contains <0.04 wt.% S, Type II rock which contains some biotite schist contains 0.04 to 0.08 wt.% S, and Type III rock with a greater proportion of biotite schist contains >0.08 wt% S.

Methodology

Four high density polyethylene tanks (lysimeters), 2 m in diameter and 2 m in height, were filled with and surrounded by waste rock to study the upper 2 m of the active zone of a waste-rock pile. Two of the active zone lysimeters (AZL) were filled with Type I waste rock (Type I west and Type I east; Figure 1) and two lysimeters were filled with Type III waste rock (Type III west and Type III east; Figure 1).

Three large-scale test piles, measuring 60 by 50 m at the base and 15 m in height, were constructed at Diavik, one with a sulfur content of an average of 0.035 wt % S (Type I test pile), and another with an average of 0.058 wt.% S (Type III test pile; Fig. 1). The third test pile constructed was based on a waste-dump closure concept that consists of a Type III core (0.08 wt.% S) covered by a 1.5 m layer of till and capped with a 3 m layer of Type I waste rock (Covered Pile). Each pile is underlain by a high density polyethylene geomembrane that captures and directs water to outflow drains (Figure 1). The Type III test pile drains to two outflow drains, Type III North and Type III South. The research site was constructed in 2004-2006, and ongoing monitoring began in 2007. Full details on the design, construction, and instrumentation of the test piles and AZLs are provided by Smith et al. (2009). Effluent samples were collected and analyzed for concentrations of SO₄²⁻, NO₃-N, NO₂-N, NH₃-N, ClO₄⁻ and Cl⁻.

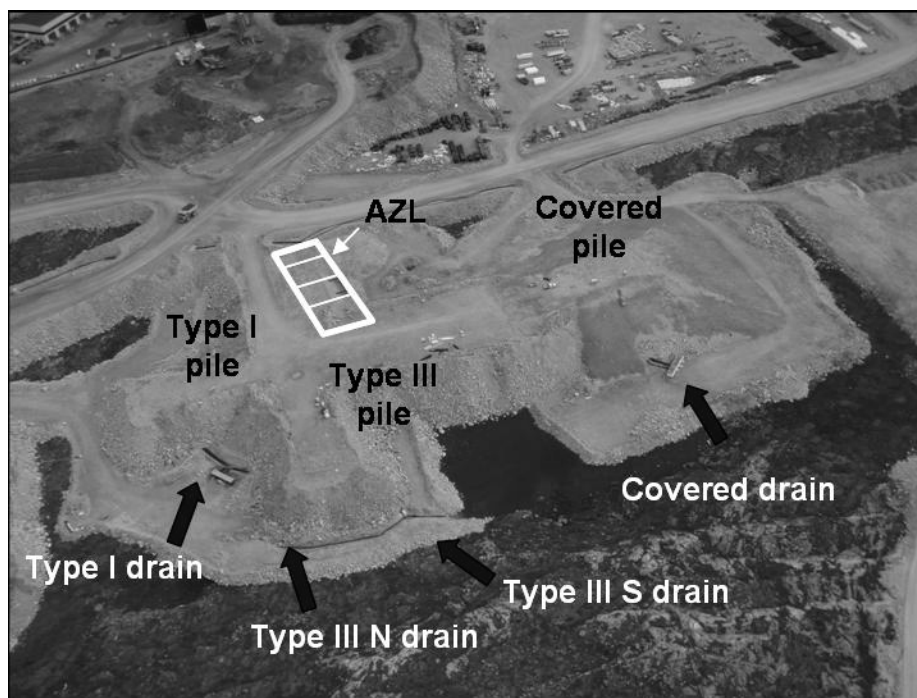


Figure 1: Test pile research facilities at Daivik

Results and Discussion

Blasting residuals comprised a large proportion of dissolved constituents in the pore water and effluent for the first three monitoring seasons (Figure 2). Release and transport of Cl^- can be used to indicate the first flush of water through the AZL and test piles, whereas irregular concentrations represent the flushing along different flow paths. Chloride concentrations are highly correlated to $\text{NO}_3\text{-N}$ concentrations. The first flush of this resident tracer indicated complex dynamics of unsaturated flow in the waste rock. Variations in concentrations and the gradual rate of dissipation of Cl^- and other blasting residuals provide an indication of the pile heterogeneity and the relative contribution of different flow paths. As temperatures within the piles increase with seasonal ambient temperature increases, larger proportions of the pile contribute to flow, and increased concentrations of blasting residuals are observed in waste-rock effluent.

The % residual N within waste-rock piles can be determined from the total mass of N released ($\text{NH}_3\text{-N} + \text{NO}_2\text{-N} + \text{NO}_3\text{-N} = \text{N}_{\text{total}}$) in effluent from the waste rock piles and determining the total N in the explosives used to blast the mass of waste rock (N_{used}). Typical $\text{N}_{\text{total}}:\text{N}_{\text{used}}$ ratios at Diavik during test piles construction ranged between 0.1 to 6 %, but were generally < 3 %. These ratios were within the typical range observed for mine sites (DDMI 2006; Pommen, 1983).

Mass-balance calculations based on the ratios of $\text{SO}_4^{2-}:\text{N}_{\text{total}}$ can be used to estimate the relative contributions of sulfide oxidation within the piles and sulfate released when sulfur in the host rock is oxidized during blasting. These calculations can also provide an estimate of S mass released during the first flush of the piles, by determining the mass of S oxidized during blasting. This research will aid in understanding the release of constituents caused by blasting and waste-rock hydrology.

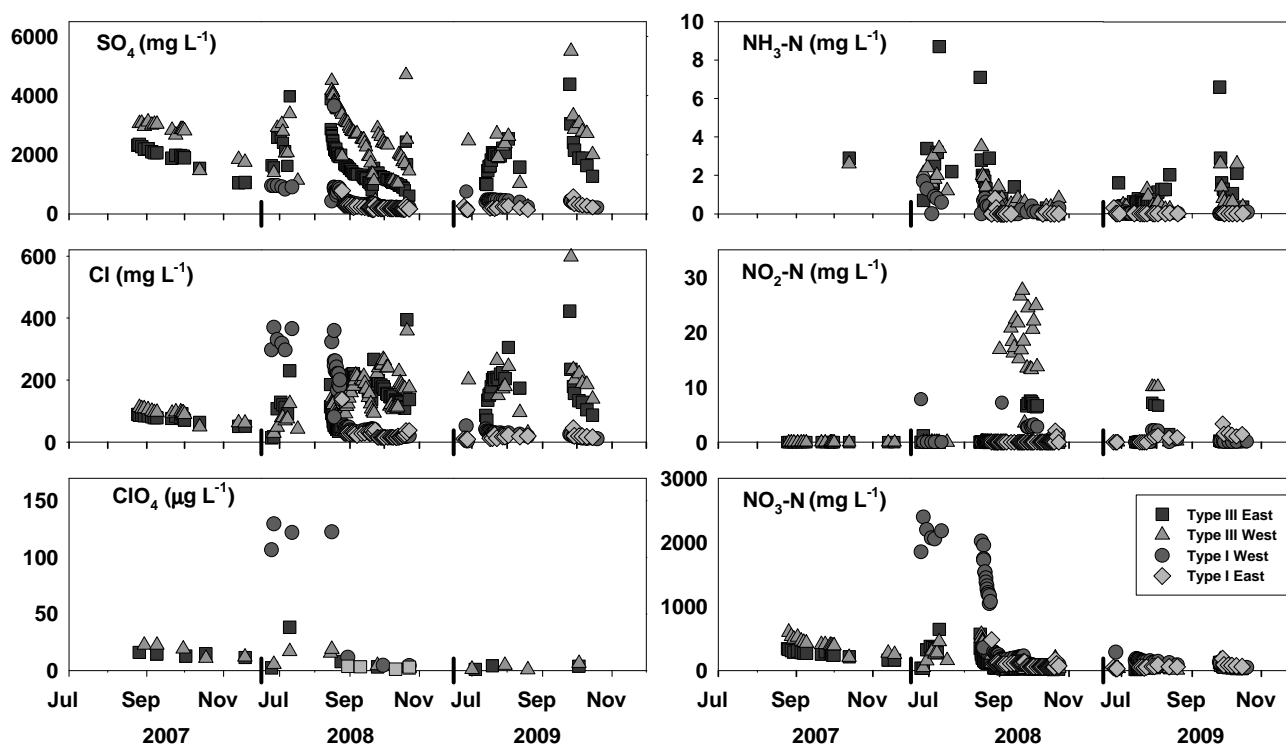


Figure 2. Blasting residual concentrations for the active zone lysimeters.

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References

- DDMI, 2006. Diavik Diamond Mine Inc. Revised Ammonia Discussion Paper. Technical report submitted to Mackenzie Valley Land and Water Board May 15, 2006
- Pommen, L.W., 1983. The effect on water quality of explosives use in surface mining. Vol. 1 Nitrogen sources, water quality, and prediction and management of impacts. British Columbia Ministry of the Environment, Victoria, British Columbia, MOE Tech. Rep. 4
- Smith, L.J.D., Neuner, M., Gupton, M., Moore, M., Bailey, B.L., Blowes, D.W., Smith, L., Sego, D., 2009b. Diavik waste rock project: From the laboratory to the Canadian Arctic. In *Securing the Future: Mining, Metals and the Environment in a Sustainable Society*, and 8th Int. Conf. on Acid Rock Drainage (ICARD), Skellefteå, Sweden. 22–26 June 2009.