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Valorization of acid mine drainage treatment sludge as remediation component to control acid generation from mine wastes, part 2: Field experimentation

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ABSTRACT

The possibility of using acid mine drainage (AMD) treatment sludge as a cover component to control AMD generation from mine wastes was investigated through laboratory characterization and kinetic column testing (companion paper). The results showed that mixtures of sludge and waste rock, and sludge and tailings, may be integrated in an AMD prevention and control strategy at Doyon mine site (northwestern Quebec, Canada). In order to further investigate these scenarios in realistic climatic conditions, instrumented field test cells were installed on site to evaluate the performance of the mixtures to control AMD generation from tailings and waste rock under natural field conditions. The main findings from two seasons of monitoring are presented in the paper. The waste rock-sludge mixture placed over waste rock was able to reduce the generation of AMD from the waste rock, therefore confirming lab results, and was able to produce a neutral effluent with low concentrations of dissolved metals. The tailings-sludge mixture placed over tailings, with an evaporation protection layer, maintained a high volumetric water content and reduced sulphide oxidation from the tailings as exhibited by a neutral effluent. Monitoring of the field cells will continue to provide valuable information on the possible sludge valorization options.

1. Introduction

The first companion paper presented experimental work done in the laboratory to evaluate the potential valorization of acid mine drainage (AMD) treatment sludge as component in mine waste reclamation scenarios to control AMD from sulphidic waste rock and tailings. The project was inspired by previous work by Zinck (2005, 2006), Zinck et al. (2010), and Zinck and Griffith (2012a, 2012b, 2013), which evaluated the use of sludge as mixtures with waste rock and tailings, and as cover material, among other usages. The sludge has high alkalinity content, provided by the alkali added during AMD treatment, gypsum formed during treatment, and other sulphate and hydroxide species. Furthermore, its fined-grained characteristics and neutralizing properties make the sludge a possible alternative as material in AMD-generating waste reclamation methods.

Experiments in the laboratory were first conducted to identify the potential mixtures that can reduce acid generation when placed over acid-generating tailings and waste rock. It was found that waste rock-sludge mixtures, when placed on waste rock, were not able to prevent the generation of AMD (see companion paper). Because sulphide oxidation was not prevented in the waste rock due to the coarse particle size and the low volumetric water content of the mixture, the neutralization capacity of the sludge was rapidly depleted, thus proved insufficient to neutralize AMD produced by the waste rock. However, the waste rock-sludge mixtures reduced metal loading in the effluent. So the disposal of sludge on waste rock could be an interesting option to reduce the dissolved metal concentrations of an effluent to regulate the feed metal loading to a water treatment plant, at least temporarily. Covers made of sludge and tailings mixture were able to reduce the generation of copper, zinc, calcium, sulphur and acidity from the Doyon tailings. These covers may also become more successful if combined with a cover to control evaporation (Demers et al., 2009).

The next logical step was to evaluate the optimal configurations determined by the laboratory tests in real conditions, at an intermediate scale. The importance of intermediate scale experiments was demonstrated by several authors, including Plante et al. (2013), Demers et al. (2009), Bussière et al. (2007), Adu-Wusu

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and Yanful (2006) and Aubertin et al. (1997). Temperature and liquid-to-solid ratio are the two main factors affecting the geochemical response of mine waste in a kinetic test (Plante et al. 2013). Intermediate scale field tests are necessary to account for the effects of transient climatic conditions on the hydrogeological behaviour of the tested material configurations, and to obtain a better estimate of the effluent quality that is expected to occur at the larger scale.

This paper presents the field work done to evaluate the effectiveness of waste rock-sludge and tailings-sludge mixtures as part of a reclamation strategy for the Doyon mine site. The Doyon site is first described, followed by the presentation of the intermediate scale field cells design, construction and instrumentation. The monitoring results of the first two seasons are then presented and discussed.

2. Doyon mine site description

IAMGOLD is one of the main gold mining companies in the Abitibi region; the Doyon-Westwood site is a gold operation located 40 km east of Rouyn-Noranda, Quebec, Canada. The Doyon mine has been in operation from 1978 to 2010, beginning as an open pit followed by underground operations. The Westwood deposit, located nearby Doyon, began production in spring 2014. AMD potential of the Doyon tailings and waste rock was not identified at the beginning of operations; therefore AMD-generating waste rock was used on the site to build roads and tailings dams. Consequently, most of the water from the site must be collected and treated before its release into the environment (Blier et al., 2012). The Doyon mine site uses a standard high-density sludge process, in which acidic water is neutralized by lime addition, thereby precipitating metal ions as hydroxides, and subsequent thickening to separate the solids (sludge) from a clear effluent. The sludge was then deposited in two storage ponds over a period of approximately 15 years (personal communication), for a volume of nearly 1 million cubic meters of sludge. Once the ponds were filled, the sludge was deposited with the tailings in the tailings ponds. Since the stop of sludge deposition in these ponds, vegetation has naturally colonized the ponds and presents impressive diversity (Smirnova et al., 2013). This observation led the operators to seek a potential reuse of the sludge in reclamation components, in part because of its ability to encourage plant growth, and because of its fined grained and neutralization properties. The Doyon-Westwood site will eventually need to reclaim several tailings ponds and waste rock piles, which are AMD-generating. They also need to reclaim the sludge storage ponds because of their location on the site; even though natural vegetation is already established and effluent quality respects the norms.

Tailings, waste rock and sludge characterization was presented in the companion paper. As a reminder, Table 1 presents selected chemical and physical parameters of the materials. Waste rock and tailings are acid generating based on static tests results (NNP < −20 kg $CaCO_3$/t), and based on field observations. Sludge has a high neutralization potential, it contains sulphur as sulphates and has a high calcium content. X-ray diffraction (XRD) identified gypsum and ettringite as major components of the crystallized fraction; however a large fraction of the sludge is amorphous therefore not identified by XRD. G_s and D_{50} in this table represent the specific gravity and the mean diameter of the particles, respectively.

Table 1
Selected characterization parameters.

Parameter	Waste rock	Tailings	Sludge
Ca (%)	2.175	2.875	18.6
Fe (%)	5.4	5.78	9.21
S total (%)	1.185	3.43	7.37
S sulphate (%)	0.39	0.38	7.5
NP (kg $CaCO_3$/t)	4.2	40.6	>203
NNP (kg $CaCO_3$/t)	−21.5	−55.7	>203
G_s	2.8	2.8	2.1
D_{50} (μm)	1600	39	25

3. Field tests cells construction and instrumentation

3.1. Cells configuration

On the basis of the results provided by the laboratory investigation (presented in the companion paper), two optimal mixtures were chosen to be tested at the intermediate scale:

- A mixture of 25% sludge and 75% waste rock (wet weights) placed over waste rock to reduce the metal loading and increase the pH of the effluent;
- A mixture of 10% sludge and 90% tailings (with 2% cement added) placed over tailings to reduce sulphide oxidation from the tailings.

Two control cells were also installed as comparison basis: uncovered waste rock and uncovered tailings. The main objective of the field cell experiment was to evaluate the hydrogeochemical behaviour and performance of the sludge-based mixtures, used to limit acid mine drainage from waste rock and tailings, under realistic climatic conditions. The cells design and construction was inspired by previous work by Bussière et al. (2007). The location of the field cells is crucial to ensure the physical integrity of the cells, their permanent access allowing the follow-up and recovery of effluents. The chosen location was on a flat section of the waste rock pile on the Doyon mine site. The cells were partly dug into the waste rock, and the portion removed was used to make side berms. The configuration of each cell is described in Table 2.

3.2. Cells construction

The first step in cells construction was the digging of the cells forms in the waste rock. Then, a 20 cm layer of fine sand was placed in the cells to provide protection for the geomembrane. The geomembrane allowed isolating the cells content and to collect all rain water that contacts the cells materials. The effluent collection system (drain) was installed by piercing a hole at the bottom of the geomembrane and attaching a drainage pipe with an outlet below the level of the cells to allow water flow. Fig. 1 illustrates the digging process and the installation of the drainage system.

Once the bottom portion of the cells was filled with the appropriate volume of waste rock or tailings as per Table 2, the mixtures were prepared on site. The waste rock and sludge mixture was prepared by mixing the right proportions of sludge and waste rock to obtain a 75% waste rock and 25% sludge mixture (wet weight). The mix was performed with the mechanical shovel, as shown in Fig. 2; however it was difficult to break all the sludge lumps (up to 30 cm diameter). After a mixing time of approximately one hour, the mixture was deemed homogeneous and transferred into the field cell. The tailings and sludge mixture was prepared in two steps. First, the tailings, cement and water were introduced in a concrete mixer at the paste backfill plant. Water addition was found to be necessary to allow for better mixing and to ensure a more homogeneous mixture. In the second stage, at the cells location, sludge was added in the concrete mixer which contained the cemented tailings, allowed mixing for 20 min, and then the mixture was poured over the tailings in the cell, as illustrate in Fig. 3. When excess water