A modified protocol of the ASTM normalized humidity cell test as laboratory weathering method of concentrator tailings.

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Abstract This paper presents an evaluation of the humidity cells as a laboratory weathering test for concentrator tailings under an ASTM protocol (ASTM D5744—07, option A). The main objective is to investigate the limit of the standard ASTM protocol, originally designed for mine wastes with particle size less than 6.3 mm (0.25 in). The results show that the humidity cells can underestimate the reactivity of concentrator tailings (characterized by a fine particle size distribution (< 200μm)), due to an excessive drying of the sample. This study proposes a modification of the normalized humidity cell test by keeping the sample continuously at a degree of saturation between 40% and 60%, under which the sample is more reactive. Results show that the cumulative amount of sulphate generated by sulphide oxidation during the 25 cycles performed under the modified protocol is 4.5 times greater than under the standard protocol. These results clearly show that tailings under the modified protocol are much more reactive than the same tailings under the standard protocol, allowing a more conservative AMD prediction.

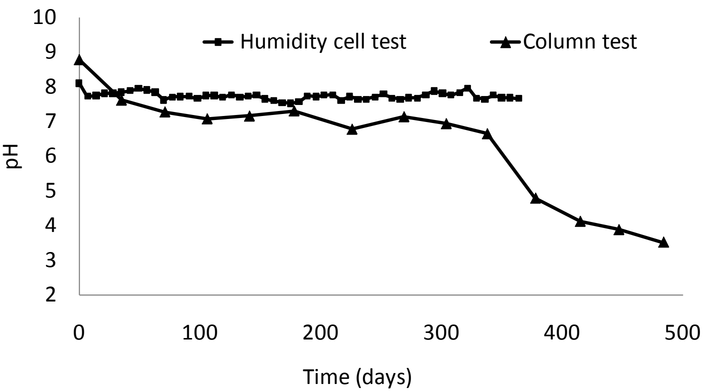
Key Words Acid mine drainage, kinetic test, prediction, humidity cells

Introduction

The mining industry generates large amounts of tailings that often contain sulphide minerals. When exposed to atmospheric conditions (water and oxygen), some tailings can produce acidity accompanied by enhanced metal dissolution. This well known phenomenon is called acid mine drainage (AMD) (Kleinmann et al. 1981). Static tests (also called Acid Base Accounting tests or ABA) are frequently used to predict AMD because they are fast and inexpensive (Villeneuve 2004). However, the ABA tests have an uncertainty zone where it is impossible to clearly state the long-term acidity production potential (Ferguson et Morin, 1991). When a given tailings is in the uncertainty interval, or when there is a need for a better understanding of the future geochemical behavior of tailings, it is necessary to perform kinetic tests. The most common kinetic tests are laboratory column tests, humidity cells tests and field-based pad tests (Lawrence 1990; Price 1997; Lapakko & White 2000; Frostad et al. 2002; Sapsford et al. 2008). All these types of kinetic tests are based on the alteration of materials under controlled conditions to evaluate their long term evolution.

Previous laboratory work had shown opposite results on AMD generation potential for the same tailings depending on the type of kinetic test used. Benzaazoua et al. (2008) noticed a certain reactivity inhibition when tailings samples are submitted to humidity cell tests normalized by ASTM standards. In his study, the pH of leachates remained neutral over 364 days corresponding to 52 cycles (fig.1). The same sample submitted to column kinetic test becomes acidic after 380 days, which corresponds to only 10 cycles (Demers et al. 2008) as showed in fig.1. Based on this

Figure 1 *Evolution of leachates pH for the same sample submitted to column and humidity cell kinetic test*



finding, and also on the work of Frostad et al. (2002), the present study focuses specifically on the humidity cell testing procedure (option A, ASTM D5744—07), the most widely used method for AMD prediction. A modification of the standard ASTM protocol is proposed in this paper and consists of maintaining the sample continuously at a degree of saturation (S_r) between 40% and 60%, instead of maintaining it at its natural value during a period of 7 days. The target S_r values (40—60%) are based on previous works that showed that a high degree of saturation (>85%) in tailings reduces the oxygen availability (Ouangrawa et al. 2009) while a low degree of saturation (<20%) reduces the water availability for the oxidation reaction (e.g. Godbout et al. 2010).

Materials and methods

The tailings selected for this study comes from the Manitou abandoned mine site (Val-d'Or, Canada) which are recognized as being highly acid generating. The sample mineralogy was determined by X-Ray diffraction (XDR) and optical microscopy analysis. Acid-base accounting (ABA) tests were conducted using the Sobek test modified by Wang and Lawrence (1997). The mineral composition and ABA test results are summarised in tab.1. The sample is mainly composed of quartz, muscovite and pyrite (at approximately 20%). No mineral with high neutralization potential is present in the sample, which is confirmed by the ABA test (neutralizing potential NP = 0).

The humidity cell tests were performed in a chamber made of Plexiglas that provided air input and output. The cells have an inside diameter of 20.3 cm and a height of 10.2 cm, and were filled with 1 kg of material (at a degree of saturation of 50%) placed on a perforated plate covered with two geo-textile layers. Dry and humid air fluxes (1 to 1.5 L/minute) and a humidifier's water temperature (25—30 °C to gives 99% air moisture: ASTM D5744—07) were maintained at constant during the test. The kinetic test was performed with two cells: the first cell followed the standard ASTM protocol (three days of dry air and three days of water-saturated air blown over the sample, followed by flushing the sample with deionized water on the seventh day), while the second one followed a modified protocol. The protocol modification consisted of keeping the sample at S_r values between 40% and 60%. The sample was initially installed in a cell with a water saturation of 50%. The degree of saturation is monitored by weighting the humidity cells, and the targeted S_r is obtained by adding deionized water to the cell during the dry and moisturized cycle. Sample saturation during the kinetic test was deduced by calculating the water loss and water gain and comparing to its initial water content, and using the following geotechnical parameters of the material placed in the humidity cell: sample thickness, diameter, specific gravity, porosity, initial water content, and the initial cell weight (with sample). Cell weights were measured 3 times a week: at the end of the sample wash (day 7), at the end of dry air period, and at the end of the moist air period.

Results

The experiments ended after 24 seven-day cycles. For each cycle and during the seventh day, 500 mL of deionized water was added into each cell for a period of 3 to 4 hours to ensure equilibrium is reached between leachate and solid, and then the leachate is drained. The volume of leachate collected was recorded and the water samples were analysed. Standard and modified protocols were compared for sulphate and iron release, pH, Eh and conductivity. Fig.2-A shows the water saturation evolution into the two humidity cells. S_r is maintained between 40% and 60% in the modified protocol, while it decreased progressively in the standard protocol over the 24 weeks of testing, until it became zero by the end of the test. In fact, the sample started to dry from the twelfth week and continued to lose water gradually until it became completely dry at week 17. Fig.3 shows the pH, Eh, conductivity, acidity and cumulative sulphates released during the humidity cells test. The weekly release rate of sulphates calculated as mg SO_4/kg/week represents the

Table 1 *Chemical and mineralogical characterization of the sample studied. AP: acidification potential (AP=$S_{sulfure}$ (wt%)*31, 25); NP: neutralisation potential (determined by acid base titration)*

	Mineralogical composition by XRD (wt %)						Chemical analysis		Kg $CaCO_3$/t	
	Quartz	Albite	Chlorite	Muscovite	Pyrite	Gypsum	S_{tot}	$S_{sulfate}$	AP	NP
Manitou tailings	44.3	6.7	3.8	22.6	20.1	2.5	13.5	0.659	415	0

pyrite oxidation rate. Al, Mg, Ca and Si are the products of silicate mineral dissolution, and not produced from neutralisation processes. After 160 days of testing, the sample in the standard protocol cell released a cumulative amount of sulphate, iron, conductivity and acidity that was much lower than for the modified protocol cell (fig. 3-F). Different values and patterns (fig. 3) are attributed to greater reactivity of the tailings under the modified protocol due to an optimal sample saturation that allowed a more important oxidation.

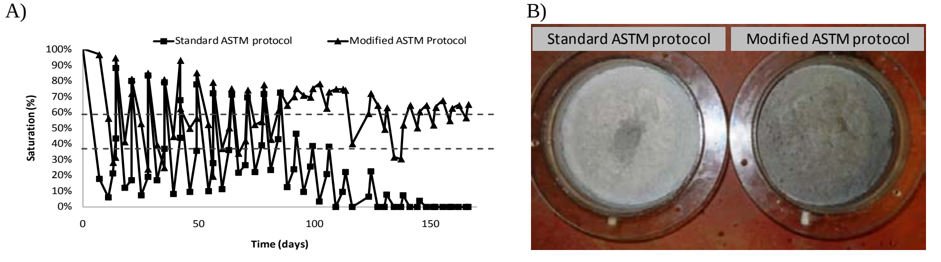


Figure 2 *A) Saturation profile in the two humidity cells. The two horizontal lines represent the targeted S_r values (between 40% and 60%). B) The picture shows that the sample in the standard ASTM protocol was completely dry at the end of the dry period of the cycle compared to the modified protocol where sample remained humid (darker colour is related to the higher water content)*

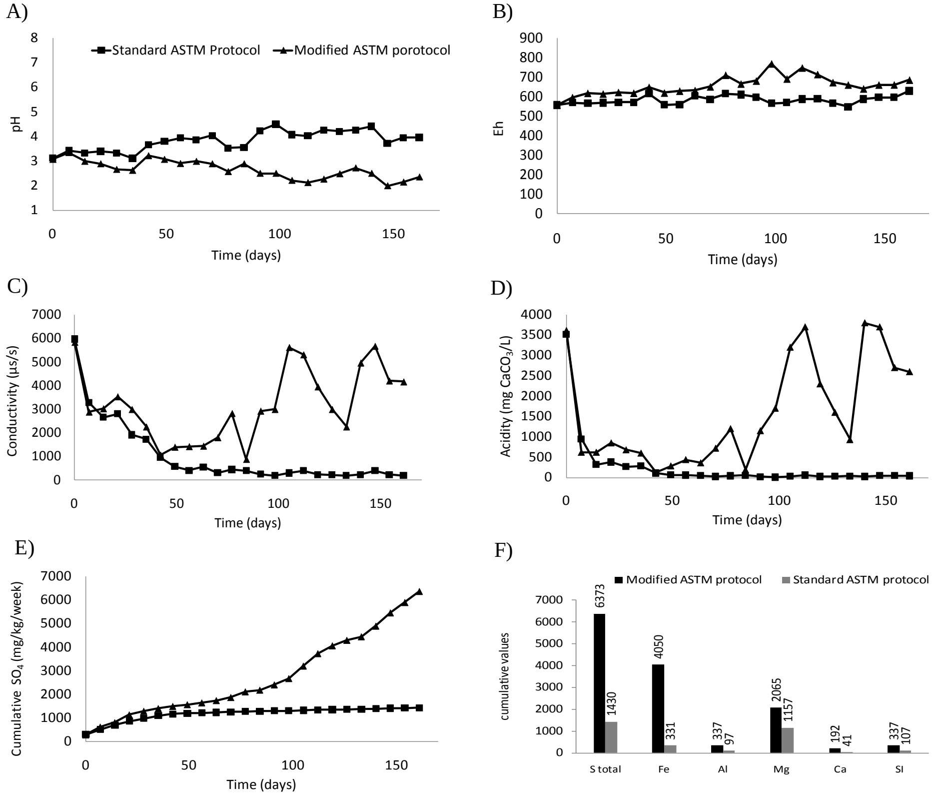


Figure 3 *pH, Eh, acidity, conductivity and cumulative sulphate, iron, release after 160 days of kinetic test*

Conclusions

A single concentrator tailings was submitted to two humidity cell kinetic tests. The first one was a standard ASTM protocol and the second one was a modified protocol, which kept the sample in a given range of saturation (40%—60%). Results showed that the standard humidity cell created unsuitable oxidizing environment due to its drying cycles. The modified protocol created the conditions that were more favourable for sulphide oxidation due to the moisture content which was maintained at an optimal level for oxidation. Based on these preliminary results, six humidity cells were set up for further investigations and are presently under testing: (i) two cell tests were conducted as duplicate of those presented in this paper; one of them was instrumented with a water content sensor for saturation measurement during the test; (ii) two cells were set up with the same sample (1kg), but the cell diameter was reduced to 10.2 cm to evaluate simultaneously the effect of the sample thickness and ASTM protocol modification on sulphide reactivity; and finally (iii) two cells (20.3 cm ID) filled with a different sample which has a lower acidification potential (AP=70 kg $CaCO_3$/t) to evaluate the sample composition effect on the two humidity cell test protocols.

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