

## Prediction of acid mine generating potential: validation using mineralogy

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**ABSTRACT:** Acid mine drainage (AMD) is a problem of major importance for the mining industry. Its prediction is very important for a proper management and rehabilitation of AMD generating sites. The Sobek test (1978) modified by Lawrence and Wang (1997) is the most used static test to predict the potential to generate AMD (particularly in North America). This method is compared in this work with mineralogy based static tests to evaluate the benefits of knowing the tailings mineralogy in AMD prediction. Three synthetic tailings composed of simple mixtures of well-characterized pure minerals are used. Although basically different in their principles and procedures, the modified Sobek test and mineralogy based static tests provide comparable results. The static prediction results are validated through the use of weathering cell kinetic tests.

**KEYWORDS:** *Tailings, Acid mine drainage, Static and kinetic tests, quantitative mineralogy,*

### INTRODUCTION

Sulfidic mine tailings can generate acid mine drainage (AMD) under atmospheric water and oxygen action. Static tests (also called Acid base accounting ABA tests) are frequently used to predict AMD potential because they are fast and inexpensive. Reliable AMD prediction can help choosing proper mine waste management strategies during mining operation and selecting the appropriate mine closure plan. So, it is imperative to adequately estimate the acid generating potential of tailings especially. However, static tests have an important uncertain zone according to Ferguson & Morin (1991). Materials located in the uncertain zone are tested in this study. The Sobek test (1978) modified by Lawrence and Wang (1997), the most used static prediction test in North America, will be compared with three mineralogical static tests (Kwong 1993; Lawrence and Wang 1997; Paktunc 1999) to compare those different tests and to evaluate the benefits of tailings mineralogical composition knowledge in AMD prediction. For the

mineralogy based prediction tests, it is absolutely essential to know the precise mineralogical composition of tailings. For the relevance of this work, 3 "synthetic" tailings were made from a mixture of pure minerals. A combination of various chemical and mineralogical characterization techniques were used to estimate the mineralogy of the mixtures with sufficient accuracy to give relatively precise results when integrated into mineralogical prediction methods.

### MATERIALS AND METHODS

In order to prepare standard mineral mixtures, pyrite (Py), pyrrhotite (Po), chalcopyrite (Cp), sphalerite (Sp), siderite (Sid), dolomite (Dol), calcite (Cal) and quartz (Qz) were acquired as pure mineral samples through a specialized distributor (Minerobec, Canada). These 8 pure minerals were further cleaned under a binocular microscope and separately crushed to reach 95% under 150µm (typical tailings grain size distribution; e.g.

Aubertin *et al.* 2002). Each pure mineral powder was characterized thereafter with a series of chemical and mineralogical techniques. More details can be found in Bouzahzah *et al.* (2008). The relative density of each mineral specimen were measured with an He pycnometer and are close to the theoretical density of the minerals except for Po ( $D_r = 4.4$ ; theoretical average = 4.61) and Sid ( $D_r = 3.8$ , theoretical 3.96). The XRD was used to identify and quantify the mineral species present in each pure mineral powder and confirmed that the Py, Cp, Dol, Cal, and Qz samples are almost pure. The Sid and Sp powders respectively show a slight contamination with rhodocrosite and quartz. The most impure sample is Po with 24 wt% pyrite and 12 wt% calcite, which explains its relative density discrepancy. The optical and scanning electron microscope observations confirm the XRD results.

The Atomic emission spectrometry (ICP-AES) results on the solids confirm the chemical purity of Py, Cp, Qz, Cal and Dol samples. The Po sample contains calcium which, after conversion into calcite, gives approximately 10 wt% of this mineral. Sid sample contains 10.3 wt% Mn and 1.86 wt% Mg, in agreement with measurements using a Scanning Electron Microscopy coupled to Energy Dispersive X-Ray Spectroscopy (SEM-EDS) analysis; again this explains the difference between the measured and theoretical density of the Sid powder.

Once the pure mineral powders characterized, 3 mixtures were manually prepared and named ML1, ML2 and ML3. They contain each of the 8 minerals in different proportions reproducing 3 mine tailings falling in the uncertainty zone of the static test used. The 3 synthetic tailings were characterized with the same techniques as for the pure minerals. Cp and Sp weight fractions were evaluated from their chemical element tracers (respectively Cu and Zn) obtained from ICP-AES analysis. Qz, Dol, and Sid samples are considered pure and their percentages in the mixtures are not

corrected. Table 1 presents the fraction of each mineral in the three mixtures before and after correction taking into consideration the contamination of Po sample by pyrite and calcite, as previously determined. The corrected mineral proportions are used for calculation of the static test parameters based on mineralogy.

**Table 1.** Corrected mineral composition (corr) of the three standard mixtures as compared to the initial dosing.

	ML1		ML2		ML3	
	Initial %	% corr	Initial %	% corr	Initial %	% corr
Py	6,50	6,86	8,50	9,34	12,00	12,48
Po	1,50	0,92	3,50	2,14	2,00	1,22
Cp	0,80	0,84	0,60	0,62	1,50	1,45
Sp	1,50	1,40	0,90	0,88	0,70	0,64
Dol	8,50	8,50	3,50	3,50	2,00	2,00
Cal	1,00	1,18	14,00	14,43	21,50	21,74
Sid	7,00	7,00	3,00	3,00	20,00	20,00
Qz	73,20	73,20	66,00	66,00	40,30	40,30
Total	100,00	99,90	100,00	99,91	100,00	99,83

## RESULTS AND DISCUSSIONS

### Static tests

According to the Sobek test (1978) modified by Lawrence and Wang (1997), the acid potential (AP) is calculated from the sulfur content of the sample, and the neutralization potential (NP) is determined by an acid-base titration. For mineralogy based static tests, the calculation methods of Kwong (1993), Lawrence & Wang (1997) and Paktunc (1999) were used. The Lawrence and Wang (1997) method uses the inorganic carbon content for NP calculation. The amount of inorganic carbon and sulfur in samples were deduced from the mineralogical compositions. The Kwong (1993) and Paktunc (1999) methods are based on the summation of individual contributions of the minerals that produce (AP) and neutralize (NP) acid. The net neutralization potential (NNP) of a given tailings is defined as the difference between its NP and AP ( $NNP=NP-AP$ ). The results obtained by the different static tests are listed in table 2 and

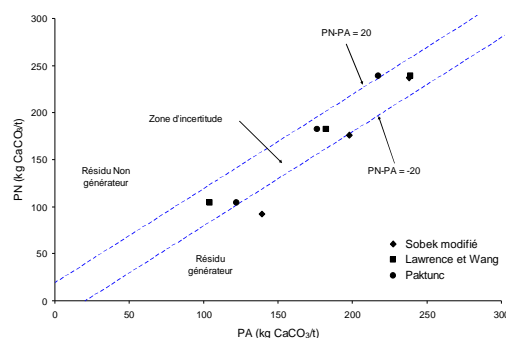
graphically plotted (Fig. 1) according to the Ferguson & Morin (1991) interpretation. All static tests used in this study classify the tailings in the uncertain zone except for ML1 classified as acid generating with the modified Sobek test.

**Table 2.** Compilation of results from chemical and mineralogical static tests used in this study. For the Kwong test, if  $M > 0$ , the sample is considered acid generating, otherwise it is considered non acid generating.

		AP (Kg CaCO <sub>3</sub> /t)	NP (Kg CaCO <sub>3</sub> /t)	PNN (Kg CaCO <sub>3</sub> /t)
Modified Sobek	ML1	139,35	91,9	-47,45
	ML2	197,8	176,3	-21,5
	ML3	238,15	237	-1,15
Lawrence and Wang	ML1	148,63	104,08	-44,55
	ML2	196,11	182,3	-13,81
	ML3	244,6	239,11	-5,49
Kwong M=PA-PN	ML1	0,16	0,08	M=0,08
	ML2	0,22	0,23	M= - 0,01
	ML3	0,31	0,38	M= - 0,07
Paktunc	ML1	122,23	104,18	-18,05
	ML2	176,33	182,24	5,91
	ML3	217,4	239,08	21,68

### Kinetic test

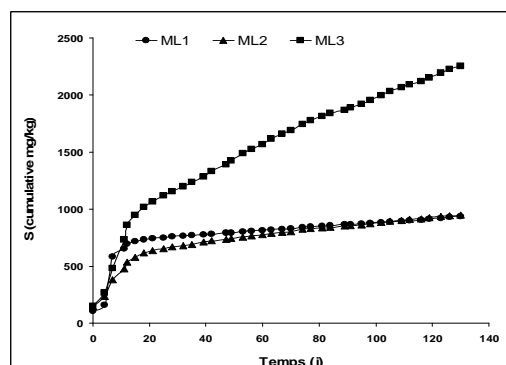
To validate the static tests results presented above, weathering cells (small-scale humidity cell tests) were performed (see Cruz *et al.* 2001 for more details on the method). The measured pHs in flushing waters show a slight fluctuation around 8 indicating that the 3 samples did not become acidic during the kinetic tests. The measured oxydo-reduction potentials (Eh) reflect oxidizing conditions as a result of sulfide oxidation. The sulfur measured in leachates (mainly as sulfate) is the product of this sulfide oxidation. Iron was not detected in the leachates since the measured Eh-pH values are favourable for its precipitation as oxyhydroxides minerals in the weathering cells. Trace levels of Mn, Zn and Cu in leachates, and undersaturation of Mn, Zn and Cu secondary minerals (determined by geochemical modeling using VMINTEQ) reflect that Sid, Sp and Cp are not oxidized during the kinetic tests. For more geochemical details see Bouzahzah (2006).

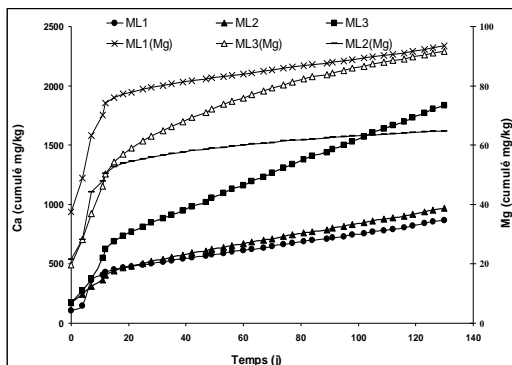


**Fig. 1.** Classification of the tree standard samples in terms of AP and NP according to Ferguson & Morin (1991).

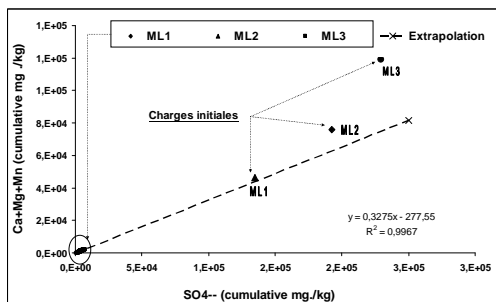
Figure 2 shows that the cumulative sulfur (as  $SO_4^{2-}$ ), Ca and Mg concentrations increase during the weathering cell tests for all samples. The cumulative Ca and Mg leaching is indicative of calcite and dolomite dissolution (related to acid neutralisation). Figure 2 also shows that the sulfide oxidation rate slows down for all tailings after a few days, and that the stabilized oxidation rate is greater for the ML3 sample than for the others, which are similar.

The oxidation-neutralization curve (Fig. 3) gives a long term prediction of AMD generation (see Benzaazoua *et al.* 2001 for more details). Assuming steady-state geochemical behaviour, the oxidation products (sulfates) would disappear before the neutralizing elements (Ca, Mg, and Mn).





**Fig. 2.** Graphical representations of the evolution of cumulative concentrations of sulfur, calcium and magnesium collected throughout the kinetic test.



**Fig. 3.** Extrapolated oxidation-neutralization curve for the long-term prediction of acid mine drainage of the tree samples (Benzaazoua & Al 2001)

## CONCLUSIONS

Many chemical and mineralogical characterization techniques were used to precisely determine the mineralogy of 3 synthetic tailings. Mineralogy based static tests are useful when sample mineralogy is known with enough accuracy and give in our study comparable results to those of the modified Sobek test. The modified Sobek test seems to overestimate the AP prediction by taking into account the sulfur from sulfides that do not seem to oxidize in the conditions of the weathering cells.

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