

Geochemical Assessment of Tailings proposed for

Marine Tailings Disposal (MTD)



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INTRODUCTION

A geochemical study has been undertaken on tailings material from a Greenland gold mine. About 1.5 million tonnes of tailing were proposed for Marine Tailings Disposal (MTD) into a nearby fjord. For this reason, **static** and **kinetic** geochemical tests have been undertaken in order to characterize the sample and assess its reactivity, leachability and possible acid generation potential. These results facilitated the decision on tailings sub-marine disposal.

METHODOLOGY

Static Tests indicate the total potential capacity of the tailings to release metals and acid by assessing acid generating and acid neutralizing minerals, sulfur and carbon concentrations. Static tests cannot be directly correlated to the natural environment but give clues on a potential behaviour.

Applied were:

- Petrographic Methods: X-Ray Diffraction (XRD), Scattered Electron Microscopy (SEM), optical microscopy
- Acid Base Accounting (ABA)
- Net Acid Generation Test (NAG)
- Four Acid Digestion
- Grain Size Analysis



Figure 2 Kinetic Batch Test

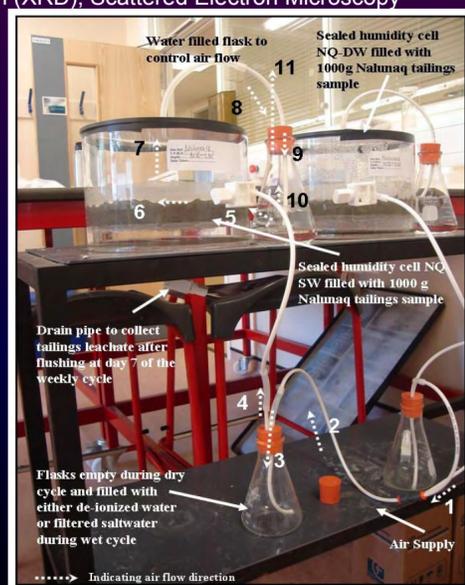


Figure 1 Humidity Cell Test

The aim of **Kinetic Tests** is the determination of rates of acid generation and neutralization together with the drainage chemistry over a period of time (Bowell et al., 2006; Mills, 1998).

Common characteristics for all kinetic testing methods are:

- Subject to periodic leaching
- Collection of drainage for analysis
- Calculation of rates of acid generation and neutralization capability depletion
- Calculation of rates of metal release
- Prediction of water quality (Mills, 1998).

Applied were:

- Standardized Humidity Cell Test for tailings (ASTM protocol D 5744, 2001, Fig.1)

Two cells were set up and run in weekly cycles over a 20-weeks period. One cell was periodically rinsed with de-ionized water, whereas the other cell was rinsed with filtered seawater. In addition to the assessment of the reactivity and acid drainage generation potential in oxic environment, this test approached the identification of differences in reactivity by using a rinsing medium of sea water.

• Kinetic Batch Tests

Additionally, a range of kinetic batch tests were undertaken (Fig.2), simulating an environment with reduced oxygen supply by maintaining the samples submerged in either de-ionized water or filtered seawater. Furthermore, effects of temperature and illumination were assessed. Some jars were held in darkness and others exposed to day light. Others were maintained at ambient temperatures, were heated to 32°C or chilled to 5°C. Weekly cycles were run over a 20-weeks period.

RESULTS

Static Tests

Acid Generating Minerals

Identified were: arsenopyrite, marcasite, pyrite and chalcopyrite (as discrete grains Fig.3, Fig.4); tetrahedrite, chalcocite; sphalerite and galena (when iron in mineral structure); jarosite

Acid Neutralizing Minerals

Calcite, ankerite, hornblende, chlorite, kaolinite, micas anorthite, ortho-feldspar

Paste pH 8.7

ABA

Total Sulfur: 0.6% Total Carbon: 0.3%

Sulfide Sulfur: 0.5% Organic Carbon: 0.1%

Sulfate Sulfur: 0.1% Inorganic Carbon: 0.2%

NP: 18.7kg eq CaCO₃/t (inorg.C * 83.3)

AP: 15.2 kg eq CaCO₃/t (Sulfide Sulfur (%) * 31.25)

AP_{cons}: 19.2 kg eq CaCO₃/t (Total Sulfur (%) * 31.25)

AP_{cons2}: 238.4 kg eq CaCO₃/t (Sulfide sulfur (%) * 62.5; Perry, 1998)

NPR: 1.2 (NP/AP_{cons(2)}); NPR_{cons}: 1.0; NPR_{cons2}: 0.5; NNP: 3.5 kg eq CaCO₃/t (NP - AP_{cons(2)})

NNP_{cons}-0.5 kg eq CaCO₃/t, NNP_{cons2}-19.7 kg eq CaCO₃/t

NAG NAG pH: 4.7 NAG : 5.9 kg H₂SO₄/t



Figure 3 Arsenopyrite (opt. micr: obj. 40, refl. light, paral. pol.)

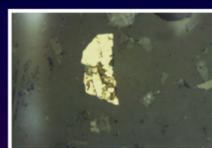


Figure 4 chalcopyrite (opt. micr: obj. 40, refl. light, paral. pol.)

Grain Size Analysis

fine sand fraction (<200 µm, > 63 µm: 26 %), coarse silt fraction (<63 µm, >20µm: 37 %) and a middle silt fraction (<20 µm, > 6.3 µm: 37 %), high concentration of clay fraction

Total Concentrations

Arsenic, bismuth, cadmium, lithium, molybdenum, lead and thallium enriched compared to crustal averages (concentration > 3*crustal average; Mason, 1967).

Kinetic Tests

Standard Humidity Cell Test

Stable alkaline pH were observed in the kinetic testwork. No elevated release of iron or sulfate from possible sulfide oxidation were observed during the testwork period.

Kinetic Batch Test

Stable alkaline pH have been observed in all batch tests. However, for the heated sample (32°C), rinsed with de-ionized water, a slight increase of sulfate and iron release has been observed during the test period (Fig.5). Hydrogen release was, nevertheless, well buffered by acid neutralizing minerals or seawater alkalinity.

Although no acid generation had been observed during the test programme for either the humidity cells or in the batch tests, the increased mobilization of elements especially at the beginning of the kinetic testwork is of environmental concern.

The following bio-available parameters breach international marine aquatic life guidelines: arsenic, cadmium, copper, nickel, lead, zinc, cobalt and iron.

International sediment quality guidelines compared against total concentrations present exceedances for arsenic, cadmium, lead, zinc, chromium, copper and nickel.

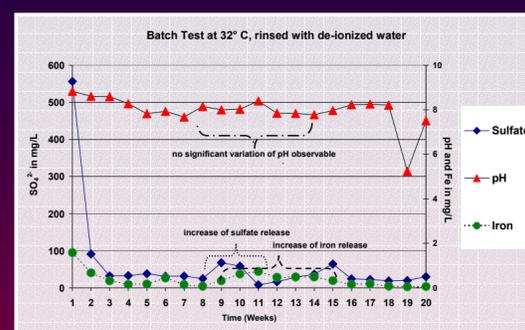


Figure 5 pH, SO₄²⁻ and Fe concentrations in heated de-ionized water rinsed batch test

CONCLUSIONS / RECOMMENDATIONS

Based on the Static Tests, the sample was categorized as of uncertain to potentially acid generating behaviour. For this reason a long term leaching test over 20 weeks duration was applied, to verify its reactivity. No acid generation has been observed during the short rinse period. Although sulfate release were enhanced during several weeks, pH remained well buffered and hence low iron concentrations were mobilized. The option of MTD was rejected due to the increased metal mobilization in relation to increased salt dissolution and pore water exchange, during the beginning of the kinetic testwork.

Result comparison of kinetic batch tests with humidity cells concluded in the following observations:

- Submerging a sample into water slows down significantly its reactivity due to the reduced oxygen supply, however, it does not prevent sulfide oxidation.
- Submerging a sample, increases significantly the dissolution of salt minerals and therewith the contaminant load in leachates.
- De-ionized water increases the mobilization and therewith the concentration in *first flush* leachates of easily mobilizable ions compared to seawater.
- Seawater buffers significantly pH and therewith slows down acid generation.
- Temperature is an important factor on the reactivity of a sample. Higher temperatures were found to enhance the reactivity of a sample, and therewith its leachate composition.
- Light exposure seems to have low influence on the reactivity of a sample.

For future MTD assessments it is recommended to substitute humidity cell tests by batch tests. However, a significantly longer test period has to be planned as to the reduced reactivity of a sample in submerged state. The rinsing medium should ideally be seawater and temperatures similar as to the proposed discharge site in order to increase comparability to on site conditions.