Red Dog Mine
Closure and Reclamation Plan

SD D4: Lime Requirements and Predicted Geochemical Changes

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Memo

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cc:		**From:**	Kelly Sexsmith
Subject:	Lime Requirements and Predicted Geochemical Changes	**Project #:**	1CT006.003

1 Introduction

As discussed in "Red Dog Mine Closure and Reclamation Plan - Supporting Geochemical Review and Interpretation" (SRK 2006), preferential oxidation of sphalerite has been suggested as an explanation for the disproportionately high release of zinc over iron. Over time, depletion of the sphalerite is expected to result in a shift towards oxidation of the iron sulfides, which could lead to a decrease in pH and increase in sulfate, iron and acidity concentrations over the longer term. Laboratory data from tailings suggests that sulfate and acidity concentrations could increase by 2.7 x as the reactions shift from sphalerite dominated oxidation to pyrite dominated oxidation. However, field data suggest that both sphalerite and pyrite are currently oxidizing in the waste rock dumps, so the transition in the field is not expected to be as significant as was observed in the laboratory.

Although there could be an increase in acidity levels, SRK does not expect that there would be an increased requirement for lime. This memo explains why.

2 Definitions

Acidity

Acidity is officially defined as the "*quantitative capacity of aqueous media to react with hydroxyl ions*" (American Society for Testing and Materials as reported in Hem, 1992). Laboratory reported measurements of "total acidity" are normally measured by titration to an arbitrarily determined end point, usually a pH of 8.3, while laboratory measurements of "free acidity" are determined by titration to a pH of 4. Measurements of "total acidity" include the acidity contributed by hydrogen ions, and base metals that form hydroxides at a pH of less than 8.3, such as aluminum, manganese, and iron, but do not normally include the acidity contributed by metals like zinc and cadmium because they do not form hydroxide minerals at this pH.

Lime Demand

In the water and load balance used to estimate post closure treatment requirements for Red Dog, SRK and Senes estimated the amount of dissolved metals that would be removed in the water treatment system. The equation used was:

$$((10^{-pH}*1000) + Al*3/27 + Fe*3/56 + Mn*2/55 + 0.5*Mg*2/24 + Zn*2/65 + Cd*2/112)*50$$

Where Al, Cd, Fe, Mn, Mg, and Zn are in units of mg/L. The resulting value was referred to as the "**lime demand**", expressed in mg $CaCO_3$ eq/L.

Inspection of the equation shows that "lime demand" includes all the components of "acidity" but also dissolved metals like zinc and cadmium. It includes only half of the dissolved magnesium concentrations, because magnesium is not fully removed by the water treatment system.

3 Estimates of Lime Demand for Pyrite and Sphalerite Dominated Oxidation

Under oxygen limited conditions, the reactions for oxidation of pyrite to ferric iron and oxidation of sphalerite to zinc can be written as follows:

$$^{4}/_{15}\,FeS_2 + O_2 + {}^{2}/_{15}\,H_2O = {}^{4}/_{15}\,Fe^{3+} + {}^{8}/_{15}\,SO_4^{2-} + {}^{4}/_{15}\,H^+$$

$$½\,ZnS + O_2 = ½\,Zn^{2+} + ½\,SO_4^{2-}$$

The "acidity" and "lime demand" for each of these reactions was calculated using the equation presented in Section 2. As shown in Table 1, although the reactions produce very different levels of acidity, they produce comparable estimates of lime demand per mole of oxygen.

In the Red Dog waste rock piles, the mixture of pyrite and sphalerite is likely to obscure even the slight difference in "lime demand" shown in the table.

Table 1: Moles of Reaction Product Released from Pyrite or Sphalerite Oxidation

Reaction Product	Pyrite Oxidation to Fe^3+	Sphalerite Oxidation to Zn^2+
moles Fe^{3+}/mole O_2	0.27	
moles Zn^{2+}/ mole O_2		0.50
moles H^+/ mole O_2	0.29	0
Calculated Acidity (mg $CaCO_3$ eq/mole O_2)	53,300	0*†
Calculated Lime Demand (mg $CaCO_3$ eq/mole O_2)	53,300	50,000†

Note: * At high zinc concentrations, some zinc hydroxides would form below a pH of 8.3 and would contribute to laboratory measurements of total acidity.

** Sphalerite typically contains some iron which results in some acidity and additional lime demand.