memo

SOLUTION[H+]

PMM14-116-D3

To: Alex Pheiffer

From: Terry Harck

CC:

Date: 15 October 2015

Re: COMMISSIEKRAAL MINE WATER QUALITY ESTIMATE

Alex

Please find below modelled post-closure mine drainage quality for Commissiekraal and a brief description of the modelling methodology.

Introduction

Predictions of mine water quality require kinetic test results. Since no kinetic test results are available at this time, a preliminary prediction of post-closure water quality in the proposed Commissiekraal underground workings was made using available geochemical characterisation data and geochemical modelling. Lack of kinetic data and the significant assumptions required in the modelling associate this preliminary water quality prediction with high uncertainty.

Geochemical modelling

Geochemical modelling used PHREEQC Interactive (PHREEQCI) version 3.1.6.9191 (20 January 2015). PHREEQCI is a computer program for performing low-temperature aqueous geochemical calculations, including speciation, saturation indices, batch reaction and 1-dimensional transport calculations. PHREEQCI can account for aqueous, mineral, gas, solid solution, surface complexation and ion exchange equilibria, as well as kinetic reactions[1]. The thermodynamic database llnl.dat was used as it contains a wide variety of minerals.

The modelling process is summarised as follows:

[1] Parkhurst DL and Appelo CAJ (2013) *Description of input and examples for PHREEQC version 3--A computer program for speciation, batch-reaction, one- dimensional transport, and inverse geochemical calculations*. U.S. Geological Survey Techniques and Methods, Book 6, chap. A43, 497 p. http://pubs.usgs.gov/tm/06/a43/

- Mineralogy results were used to develop a composite mineral assemblage for coal seam, roof, and floor material
- The equilibrium interaction of water and the combined mineral assemblages of the coal seam, roof, and floor materials at different L/S[2] was simulated in PHREEQC
- The partial pressure of oxygen (pO_2) was varied over three orders of magnitude from -0.7 (atmospheric O_2) to -3.7 (0.001 atmospheric O_2) to assess the impact of oxygen availability on pyrite oxidation

Assumptions and Limitations

- Since the mine workings will take a long time (10 to 20 years) to fill with water, water quality can be estimated from equilibrium conditions
- The composite mineral assemblage is representative of all roof and floor seam rocks exposed in the workings at closure
- Atmosphere in partially-flooded mine workings contains carbon dioxide (pCO_2=-2) and oxygen
- Trace element concentrations (Ag, As, B, Bi, Cd, Co, Cr, Cu, Mo, Ni, Pb, Sb, Sn, Sr, U, V, Zn) are not solely dependent on mineral solubility and are not included in the model
- Chlorite, Lizardite, and Microcline are not included in the llnl.dat database. The following substitutions were applied in the model:
    - Clinochlore and Chamosite simulate Chlorite
    - Chrysotile simulates Lizardite
    - Sanidine simulates Microcline

  Although the chemical compositions are similar, the impact on mine water quality is approximate since the mineral solubilities are different.
- Pyrite and calcite are the only minerals in the coal seam that are significant in terms of affecting water quality
- Based on the ABA results, the calcite and pyrite concentrations in the coal are 0.08% and 2.85% respectively
- Water in the mine workings can interact with coal seam, roof, and floor material to a depth of 0.1 m or less
- Based on a pillar width of 20 m and a coal seam height of 3 m, the relative areas of exposure of the coal seam, roof, and floor are 9%, 45.5%, and 45.5% respectively
- The L/S in the workings is about 13
- Initial water in the simulation is the average of water extractions on roof/floor samples at L/S=4

[2] L/S is the Liquid/Solid ratio determined from the masses of the solution and solid components of the system

Due to the assumptions and inherent limitations of predictive modelling, the model results presented in this memo are order of magnitude estimates. Therefore, results do not indicate modelled concentrations less than 0.1 mg/L.

Results

Sufficient oxygen was available at all modelled concentrations to completely oxidise all available pyrite. Variation in L/S was found to have a significant influence on mine water quality (Table 1).

Table 1: Summary of geochemical modelling results of Commissiekraal post-closure mine water quality

Water quality Parameter	Unit	Initial water quality	Modelled mine water quality (L/S=20)	Modelled mine water quality (L/S=10)
pH	pH units	8.1	7.6	7.6
Na	mg/L	31	31	31
K	mg/L	3.6	2.7	3.4
Ca	mg/L	10	27	47
Mg	mg/L	2.7	444	787
F	mg/L	1.2	1.2	1.2
Cl	mg/L	11	11	11
SO_4	mg/L	40	1 493	2 939
Alkalinity	mg/L	81	422	377
Al	mg/L	0.6	<0.1	<0.1
Fe	mg/L	0.1	<0.1	<0.1
Mn	mg/L	0.02	<0.1	<0.1

Conclusions

The model simulates filling of the mine workings after closure. Modelled interaction of groundwater with the exposed coal and rock in the mine workings indicates pyrite oxidation resulting in elevated concentrations of sulphate (SO_4) in mine water. Under equilibrium conditions pyrite oxidation is relatively insensitive to the modelled concentration of O_2 in the mine atmosphere.

The equilibrium model suggests that the neutralisation potential of calcite and silicate minerals is sufficient to buffer pH at neutral. However, the concentrations of several parameters including calcium (Ca) and magnesium (Mg) increase significantly through interaction with coal and rock exposed in the workings.

Based on the model results post-closure decant from the proposed Commissiekraal underground workings is estimated to have neutral pH with elevated concentrations of Ca and Mg. The model results suggest a range of 1 500 mg/L to 3 000 mg/L sulphate. Model results suggest Al, Fe, and Mn concentrations are unlikely to be of concern.

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