Geochemical and Hydrogeological Considerations from Backfilling of Discard and Ash

Koovila Naicker, Terry Harck and Nico Bezuidenhout

Golder Associates Africa (Pty) Ltd, Midrand, SOUTH AFRICA, knaicker@golder.co.za

ABSTRACT
The risks associated with discard backfill options in open cast coal pits have been assessed by simulation of pit water and salt balances. Three options were studied: coal discard backfill; mixing of discard and power station fly ash; and layering of discard and fly ash. The pore water concentrations within each option under unsaturated conditions were modelled and a hydrological model was developed. Ash disposal in both layered and mixed configurations contributed to higher levels of selected trace metals (As, B and Hg) in seepage, resulting in a higher salt load mobilised into the pit water compared to the discard only option. The mixed options reduced the ARD potential of the discard component of the mixture, provided a capillary break could be established between the mixed waste and the cover material. Due to the limited alkalinity of the ash, it was found that the mixed waste will in time acidify. The Layered option was found to have the lowest long-term environmental risk due to alkalinity from the ash leaching to underlying discard material and thereby delaying the onset of acidic conditions and reducing ARD formation rates. Groundwater impact from the pit was found to be minor as the final void is sized to evaporate more water than groundwater inflows resulting in a nett groundwater gradient towards the pit

Key Words: unsaturated, capillary break, humidity cells, mixed waste, nett groundwater gradient.

INTRODUCTION
The objective of the geochemical and hydrogeological assessment of backfill scenarios for an open cast coal pit was to assess the groundwater quality impacts of various discard/ash backfill options relative to the Base Case (backfilling with discard), so as to select the option with the least potential for groundwater contamination in terms of the requirements of South African environmental legislation. Three backfill options were considered:

- Base Case – coal discard only
- Layered Option – ash layer over discard
- Mixed Option:
  - Mixture A (9.8% ash, 90.2% discard)
  - Mixture B (15% ash, 85% discard)
  - Mixture C (24.4% ash, 75.6% discard)

Both layered and mixed disposal scenarios include a 37 m thick layer of interburden placed at the base of the pit and are covered by a 3 m layer of overburden to limit oxygen diffusion and water infiltration into the underlying material.

The Mixed option (Figure 1) comprises two alternatives: a 2-layer case and a 3-layer case. The 2-layer case will consist of a lower bench comprising a 35 m layer of discard+ash covered by a 3 m layer of mixed overburden+ash. This is overlain by a second bench of 35 m of discard+ash covered by 10 m of overburden+ash. The 3-layer case consists of a 33 m, a 19 m and a 12 m layer of discard+ash. The layers are separated by 3 m layers of overburden+ash and a 10 m layer of overburden+ash caps the sequence.

The Layered Option consists of two 35 m layers of discard+ash separated by a 3 m overburden+ash sealing layer. The ash layer caps the system and will be 32 m thick.

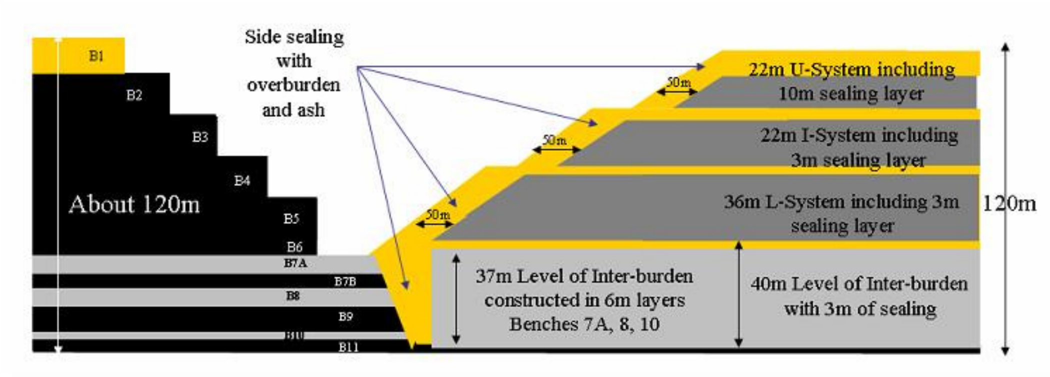

Figure 1. Conceptual cross section of mixing option

Study Methodology

Sampling and analyses were conducted on a total of 35 individual and/or composite waste samples (fine overburden, coarse overburden, plant discard, fly ash, coarse ash, conditioned ash from the ash dump, and conditioning water qualities from power station). The geochemical characterisation involved standard static and kinetic (humidity cell) testing. Geotechnical analyses included particle sizing, bulk density testing, saturated hydraulic conductivity testing and soil moisture retention properties.

In general, the modelling consisted of 4 key modules:

- A seepage module
- A geochemical module;
- A surface water module (part of the operational pit model); and
- A groundwater module.

Unsaturated modelling assessed the moisture retention within backfill materials using the geotechnical analysis results and the Vadose/W software package to model unsaturated flow process for each disposal scenario. Geochemical modelling assessed the seepage quality from the backfill material and the pit water quality using the PHREEQC and Geochemists Workbench software packages to model equilibrium water quality composition and identifying key geochemical and mineralogical constraints influencing pore water quality.

Goldsim models were used to develop time series probability density functions of the operational phase pit water volumes and salinity. The Goldsim models were supported by deterministic models that assessed specific geochemical and flow processes

The MODFLOW numerical groundwater model was used to simulate flow and mass transfer in the closure phase. Input was provided by the deterministic models simulating flow and geochemical processes. The numerical groundwater model was used to simulate the re-filling of the pit, long-term steady state water levels and potential impact on the surrounding groundwater. The integration of the modelling for the closure phase of the opencast pit is presented in Figure 2.

INTERPRETATION OF ANALYSIS RESULTS

Mineralogy

The XRD results indicated that most minerals present in the ash material are aluminosilicates and will not contribute to ARD except as buffers under highly acid conditions. Between 1% and 15% pyrite were recorded for mixed discard samples. The variability reflects variability in geology, plant operational parameters and/or sampling

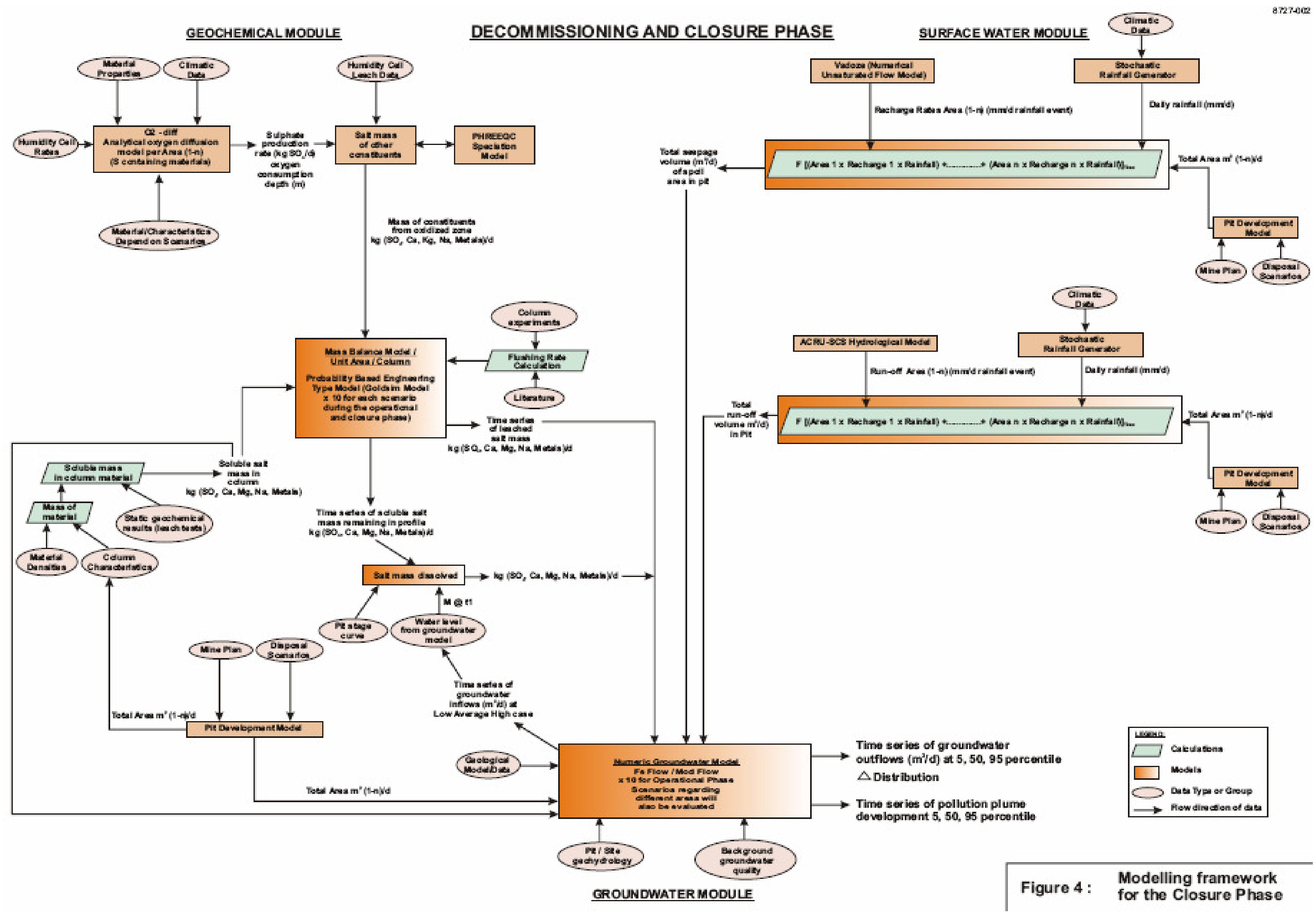

Figure 2. Modelling framework for the closure phase

Acid base accounting

Figure 3 and Figure 4 summarise the ABA characteristics of the materials, Figure 3 indicates that the AP is much higher than the NP for all materials. This implies that all backfill materials (except ash and one overburden sample) are likely to be acid generating. This includes the discard-ash mixtures.

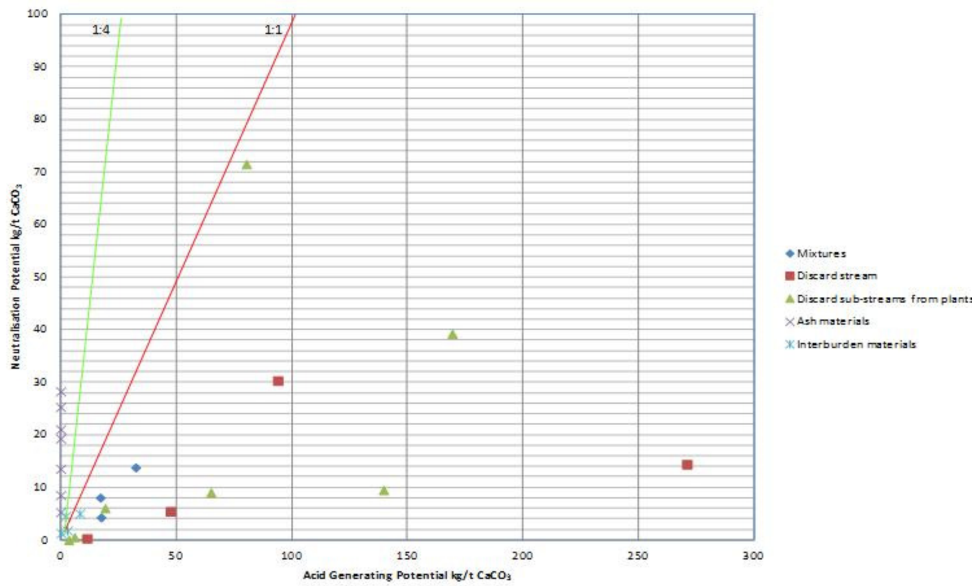

Figure 3. Plot of NP vs AP

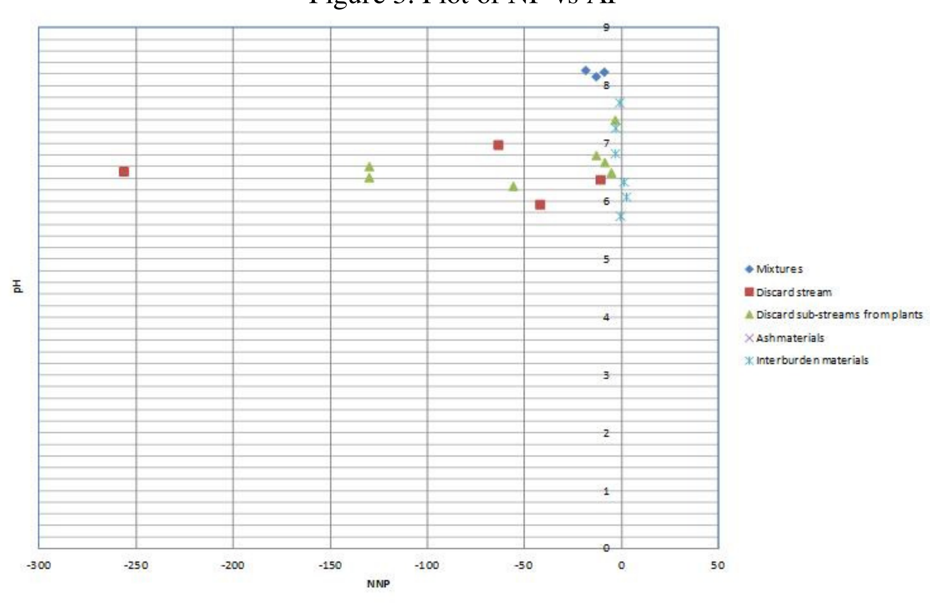

Figure 4. Plot of pH vs NNP

Figure 4 indicates that paste pH values in the various samples are slightly acidic (discard and interburden material) to alkaline (ash and discard-ash mixtures). The paste pH corresponds with the overall characteristics of the materials and the negative NNP confirms the more dominant acid generating characteristics of the discard, compared with the alkaline ash. Note: Ash pH values are from 1:4 distilled water leach tests and not paste pH values, which imply that ash pH may be significantly higher in a paste.

Leach Test

Distilled water and acid leach tests (EPA 1312) in a solid to liquid ratio of 1:4 was performed to identify the potential elements of concern. The results indicated that:

- The leachability for backfill material is reflected by maximum elemental concentrations:
  - Overburden material for Al, Cu, Fe, Na, Pb, Si, Th and Zn;
  - Discard for K, Mg, U, Mn, Ni, Co and TDS; and
  - Ash for Alkalinity, SO_4, B, Ca, Cd, Cr, Hg, Li, Mo, Se and Sr.
- Under acid leaching conditions maximum leachability is: