

Abstract

The generation of acid mine drainage (AMD) in the mining industry has been identified as a significant threat to water security by the South African government, research community and civil society. AMD is characterized by low pH and high concentrations of metals and sulphate. Several types of treatment techniques such as neutralisation, ionic resins, flotation, adsorption, coagulation, precipitation, flocculation and filtration processes have been developed to mitigate the AMD threat and produce solutions of acceptable standard for re-use or discharge. The high complexity and capital costs associated with the above processes, however, has led to a search for inexpensive and simpler process routes. The aim of this study was to evaluate the process of neutralising AMD with uncalcined waste coal discards, in order to generate a solution with water quality suitable for domestic, livestock drinking, irrigation and industrial use

Neutralisation tests were conducted in polypropylene columns, loaded with waste coal samples from Exxaro, Forzando and Vlakfontein coal mines. The columns were irrigated continuously in an open circuit with AMD solution at 0.44 mL/minute and 2.01 mL/minute irrigation rates, at a set point temperature of 25°C. The treated solutions were collected at the bottom of the columns and accumulated in tanks. The waste coal samples were crushed to -40 mm, -12.5 mm and -6.3 mm respectively, to investigate the effect of particle size. The treated AMD solution had a pH of 2.82 as well as high concentrations of sulphate (19365 mg/L), iron (6325 mg/L), calcium (492 mg/L), aluminium (424 mg/L), manganese (103 mg/L), silicon (90.6 mg/L), zinc (12.5 mg/L) and copper (10.9 mg/L). The Exxaro, Forzando and Vlakfontein waste coals contained a neutralising potential (NP) of 0.49 %, 2.33% and 2.32 % respectively, expressed **as calcium carbonate equivalent**. The coal samples also contained 0.4 % to 1.2% inorganic sulphur, which is potentially acid generating.

Neutralising capacities for Exxaro coal in columns were between 0 and 292 L AMD / t coal at crush sizes of -12.5 mm and -6.3 mm respectively. Neutralising capacities for Vlakfontein were between 0 and 2118 L AMD / t coal at crush sizes of -40 mm and -6.3 mm respectively. The neutralising capacity of the Forzando coal was 929 AMD / t coal at a crush size of -6.3 mm. The higher neutralising capacities exhibited by the Vlakfontein and Forzando coals is consistent with the higher NP values and the presence of calcite and dolomite identified by XRD in the Vlakfontein head. The results indicated that the neutralising capacities increased with a decrease in crush size, as well as a decrease in irrigation rate. It was believed that the alkaline minerals in coal were more liberated in smaller particles than in coarse particles. Therefore, the increase in the neutralising capacities with a decrease in crush size may be due to higher degree of liberation of alkalinity in the finer particles.

The alkalinity in the waste coals and concentrations of calcite, dolomite and kaolinite minerals decreased extensively during AMD neutralisation, suggesting that these minerals were responsible for neutralisation. For example, the Vlakfontein waste coal contained kaolinite (>50%), calcite (5 to 15%) and dolomite (<5%) minerals before AMD treatment. After AMD treatment, the levels were reduced to 15 - 30% (kaolinite), <3% (calcite) and <3% dolomite, which proved that they took part in the neutralisation reaction. This is consistent with literature, which suggests that out of the many types of alkaline compounds present in rocks, only

carbonates and clays are the most effective neutralising minerals. The alkaline minerals were not completely consumed during AMD neutralisation. This therefore suggests that the waste coal samples are not likely to produce AMD after use.

The treatment of AMD with waste coals resulted in the extensive removal of metals such as aluminium (98-100%), copper (84-87%), silicon (91-98%), iron (100%), zinc (36-89%) and sulphate (72-82%). However, the concentrations of undesirable species in AMD such as sulphate and magnesium (-125 – 28%) still remained above the minimum criteria required for water for domestic, livestock drinking, aquatic ecosystem, irrigation and industrial use. Furthermore, there was an indication of a significant leaching of magnesium from the waste coal into the solution. An additional polishing step should therefore be added to reduce magnesium and sulphate further to acceptable levels, for example, the Mintek SRB (sulphate reducing bacteria) process.

A desktop economic model was developed to compare the neutralisation of waste coal with the traditional route of lime neutralisation in tanks. The model was based on an AMD production of 1750 m³ / day, a neutralising capacity of 1.4 m³ AMD / t coal, a solids bulk density of 1 t / m³ and a heap height of 6 m. A lime cost of R2000 per tonne and a lime neutralising capacity of 12 kg Ca(OH)₂ / m³ AMD was used, as well as an electricity cost of 86 cents / kWh.

Capital costs were estimated at R18 million for lime neutralisation, R63 million for coal neutralisation and operating costs were estimated at R24.5 million for lime neutralisation and R18 million for coal neutralisation. Although the capital cost for waste coal neutralisation exceed the capital costs for lime neutralisation, the operating costs for AMD treatment with waste coal are significantly lower than the operating costs for AMD treatment with lime. Therefore, the investment spent on capital costs for waste coal neutralisation could be recovered over time due to the saving in the operating costs (lower than that lime neutralisation operating costs) of this option.