

Abstract

The wastes generated from both operational and abandoned coal and metal mining operations are an environmental concern. These wastes, including acid mine drainage (AMD), are normally treated to abate the devastating effects they have on the environment before disposal. At the moment, the most widely applied methods for remediation of AMD is the high density sludge process (HDS) which involves chemical-neutralization. Although the HDS process is relatively cheap and easy to operate, it has several disadvantages. These include; the formation of gelatinous sludge which is difficult to filter, sludge handling problems due to the low solids concentration resulting in considerable water losses and a large land area is needed for sludge disposal. In light of the disadvantages of the HDS process, this study was conducted to develop process flowsheets to recover iron (Fe) and aluminium (Al) which were used to produce a poly-alumina-ferric sulphate (AMD-PAFS) coagulant for water treatment. The flowsheets were developed with the understanding that the recovery of Fe(III) and Al(III) would reduce the sludge volume by over 90%, more so act as a source of revenue to partly offset the treatment cost.

The first part of this experimental program focused on developing an understanding of the oxidation of ferrous iron, Fe(II) to ferric iron, Fe(III) using air in the pH range pH of 5.0-7.0. Synthetic AMD, prepared using ferrous sulphate and aluminium sulphate salts, was used for this part of the experimental program and contained only Fe(III) and Al(III). This was done to evaluate the effect of pH, the Al(III) cations and seeding on the Fe(II) oxidation rate. The results showed that the Fe(II) oxidation rate was dependent on pH. At pH of 5.0, the average oxidation rate was 2.16 mg/L/min. The oxidation rate increased to 7.73 mg/L/min with an increase in pH to 7.0. The studies revealed that the oxidation rate was first order with respect to Fe(II) in the pH range 5.0-7.0. The order of reaction with respect to OH^- was 1.35. In the oxidation-precipitation reaction, seeding, regardless of the seed concentration, was found to increase the rate of oxidation. For example, the oxidation reaction rate increased from 2.16 mg/L/min in unseeded

experiment to 2.7 mg/L/min at pH 5 for seed concentration, $C_s = 0.5$. The study also demonstrated that Al(III) cations did not affect the Fe(II) oxidation rate.

The iron oxidation experimental program was followed by precipitation studies to recover both Fe(III) and Al(III) using sodium hydroxide. The co-precipitation of Fe(III) and Al(III) was carried out at the pH range of 5.0-7.0. Real AMD was used in these tests. In order to improve the precipitate particle size and subsequent settling and dewatering capabilities, seeded precipitation was employed with the single pass precipitate used as recycle sludge. Three different recycle sludge concentration levels ($C_s = 0.5, 1.0$ and 2.0) were studied. The results showed that at pH 5.0, a precipitation yields of 99.9 and 94.7% for Fe(III) and Al(III), respectively were obtained. An increase in the pH to 7.0 increased the recovery of Al(III) to 99.1%, while the recovery of Fe(III) remained the same. An attempt was made to relate the effect of seeding on the precipitate settling rates and it was established that the sludge settling rate and particle size improved with increase in seed concentration from $C_s = 0.5$ to $C_s = 1.0$. Above a C_s of 1.0, there was no significant improvement in the settling rate. The precipitate was used to produce a coagulant (AMD-PAFS^p) consisting of 89.5% and 10.0% Fe(III) and Al(III), respectively by dissolving the AMD precipitate in 5.0% (w/w) sulphuric acid.

A solvent extraction process was also evaluated to extract Fe(III) and Al(III) from AMD using Cyanex 272 in Shellsol D70. Cyanex 272 concentration of 0.16 M – 0.63 M was tested in the pH range 1.5-3.0. The Fe(III) and Al(III) stripping was carried out using 1.0, 2.0 and 3.0 M sulphuric acid. The number of stages required for both extraction and stripping processes of Fe(III) and Al(III) was also evaluated. The experimental results showed that quantitative removal of Al(III) >99.0% and Fe(III) >99.0% in a two-stage extraction stage using 0.47 M Cyanex 272 at pH 2.5 and 25°C is achievable. A single-stage stripping of both elements was achieved using 2 M sulphuric acid. The strip liquor contained 91.7% Fe(III) and 8.33% Al(III) and was subsequently used as a coagulant (AMD-PAFS^{sx}).

The treatment of the brewery wastewater using 10-150 mg/L AMD-derived coagulants shows that the AMD-derived coagulants were as effective as the poly ferric sulphate coagulant (PFS) in the brewery wastewater treatment. The turbidity removal was 91.9

and 87.8%, while the chemical oxygen demand (COD) removal was 56.0 and 64.0% for AMD-PAFS^p and PFS coagulants, respectively. The AMD-PAFS^{sx} showed slightly better performance as compared to the AMD-PAFS^p coagulant. This was attributed to the possibility of co-extraction of manganese and magnesium, which in itself has been used as a coagulant. The developed process, especially the precipitation based process, which can easily be incorporated into existing AMD treatment plants, not only reduces the sludge disposal problems but also creates revenue from waste.