

Executive Summary

Background

Morgan *et al.* (2005) developed a method of forming “stable” ferrite precipitate from ferrous iron present in simulated acid mine drainage, called the ambient temperature ferrite process (ATFP). The ferrite product is stable under ‘normal’ conditions, since it will not dissolve at a pH of 2, and therefore does not require slimes dams or lined ponds for storage. More importantly, the ferrite is used in coal mining operations for the separation of coal fines, and therefore has a use and possible value, and stockpiling may never occur. Therefore, by producing ferrite rather than the more regular ferric hydroxide product, the iron sludge disposal issues surrounding the treatment of acid mine drainage could be significantly reduced.

The process developed by Morgan *et al.* (2005) has a major negative impact to the receiving water body in that the pH of the water leaving the ATFP is 10.5. This water is not suitable for discharge, and this severely limits the application of the technology.

The ATFP was developed at laboratory scale using a synthetic mine water made up of ferrous sulfate, sodium sulfate and hydrochloric acid. The pH adjustments were made using sodium hydroxide, and aeration was achieved using bottled air. Calcium was identified as an inhibiting ion in the formation of ferrite.

In order for the ATFP to operate ‘properly’, the removal of ferrous iron from solution and the production of ferrite from this ferrous iron precipitate needs to occur. The first requirement is for the treatment of the water, where iron removal is the objective, while the second requirement of making ferrite is so that the process is sustainable, since ferrite seed is required in the process to make ferrite.

Aims

In order to determine the economic feasibility of the ATFP process developed in the laboratory by Morgan *et al.* (2005), a larger scale operation was required treating real acid mine drainage and reagents more likely to be used on a larger scale. Therefore, Environmental Technology Agencies were contracted to determine the following:

1. To select the most suitable site for the pilot scale test.

2. To prove the technology at laboratory scale treating actual AMD instead of a simulated mixture, using compressed air instead of bottled air, and using lime instead of sodium hydroxide.
3. To design and construct a portable pilot scale plant that can readily be transported from mine to mine.
4. To prove the technology at pilot scale at a mine and develop design and operating parameters that will allow confident up-scaling to full-scale plants.

Pilot plant and initial findings

The following was achieved:

1. Grootvlei mine was chosen as the site for operating the pilot plant, due to its proximity to the operating staff and analytical laboratories.
2. Harmony Gold acid mine drainage was delivered by Harmony Gold to the laboratory, and this was used to operate the ATFP using lime and compressed air in the same laboratory equipment used by Morgan *et al.* (2005) at UCT. Harmony water was used since it was similar in composition to the water used by Morgan *et al.* (2005). However, the source of water was approximately 60 km from the laboratory, and the development was limited by the transportation of water. Even with these limitations, the following could be reported:
 - a. Ferrous iron and other divalent metals were completely removed from the acid mine drainage;
 - b. Although inconclusive due to the limited water supply, ferrite production was observed in the process. This was inconclusive since only about 20% of the sludge in the system could be new sludge, and therefore a complete analysis of the crystal structure would not be conclusive.
3. Based then on the design parameters developed by Morgan *et al.* (2005), a pilot plant ATFP was built and commissioned at the Grootvlei mine no 3 shaft. This plant was operated for several months, but was unable to successfully remove the ferrous iron from solution, and the plant was never operated to the extent that ferrite production could begin. There were several possible reasons for this failure, and it was decided to answer some of these questions at laboratory scale before operating the pilot plant further.

At this point, it was evident that **Morgan *et al.* (2005) developed the ferrite production process thoroughly, but did not investigate the removal of ferrous iron from the acid mine drainage to the same extent.** This is the main reason for the effluent pH of 10.5 from the ATFP.

Problems encountered with the pilot plant operation

Operating the contact stabilization reactor at a pH of 10.5 using low grade lime is difficult due to the high solids load in the system. Grit accumulation from the lime is problematic and the effluent quality in terms of colour and solids is below par. By reducing the operating pH of the contact stabilization reactor and therefore the pH of the discharge water, the grit problems as well as the effluent pH limitations would be reduced.

It was not known from the laboratory-scale work whether the ATFP would work at a lower operating pH in the contact stabilization reactor, and what adjustments to the operating parameters were necessary in order to get the process to work.

Since the laboratory work had been performed at a feed ferrous concentration of 1200 mg/L, while the ferrous concentration in Grootvlei mine water is less than 100 mg/L, the operation and therefore scale-up of the contact stabilization reactor was not optimized. It was decided to perform tests in the laboratory in order to answer the questions surrounding the contact stabilization reactor, where the parameters that required further development were:

- a. The influence of the ferrous iron concentration in the acid mine drainage
- b. The operating pH of the contact stabilization reactor
- c. The required hydraulic retention time in the contact stabilization reactor
- d. The required ferrite seed concentration in the contact stabilization reactor
- e. The upper limit of the ferrite intermediate concentration and the influence of pH on this limit
- f. The ferrite intermediate concentration on the seed
- g. The anion concentrations in the feed.

Results and discussion

Laboratory tests showed that the contact stabilization reactor could be successfully operated at a pH as low as 7.5, to remove ferrous iron from Grootvlei mine water and produce a sludge that is possibly conducive to ferrite formation. Once again, the ferrite

production was inconclusive since the mass of seed required to remove the ferrous from solution results in a sludge age of many months. However, the operating conditions that were successfully tested were a hydraulic retention time of 30 minutes, mainly due to the dissolution of lime, a pH of 7.5 and a seed concentration of 5 g Fe/L, and this gives a possible operating point for the contact stabilization reactor.

These results indicate that there is scope for ferrous iron removal from water such as acid mine drainage at an operating pH of as low as 7.5, which has many advantages over the process developed by Morgan *et al.* (2005). However, the contact stabilization reactor needs to be investigated further in order to optimize this operation. The oxidation and aging processes then need to be investigated further to determine practical means of operation, since the laboratory methods can not be scaled-up.

These results can then be proven at pilot scale using the existing pilot with the required modifications.

Conclusions and recommendations for further study

It is evident from the results that the gap between the laboratory-scale process and a continuous pilot-scale process was too large, and more work is required in developing scale-up parameters before a pilot plant can be operated. It is expected that a further three years is required to finish the development work, and this will take place in three stages.

- i. The first stage will further investigate the operation of the contact stabilization reactor, firstly to confirm the results obtained to date, and to further define the operating window for this unit operation.
- ii. The second stage would investigate the formation of ferrite under 'real' conditions, where sufficient product is produced to conclusively determine whether ferrite is being formed or not. The oxidation process will not be investigated extensively, but the aging operation will be.
- iii. The third stage will be to modify the existing pilot plant to resemble the required process from stage two, and will be operated for a year to collect sufficient operating data and experience so that a full-scale plant can be designed with confidence.

