

## Executive Summary

This project was commissioned in response to an opportunity to implement the ambient temperature ferrite process (ATFP) as part of the CSIR Alkali-Barium-Calcium (ABC) Desalination Process that was to be installed at the East Rand Proprietary Mines (ERPM) site in Germiston, Gauteng, treating 100 ML/d of acid mine drainage (AMD). The ATFP was developed previously at pilot scale, but the results were negative in terms of iron removal, and the development was continued at laboratory scale (WRC Research Project K5/1640). Once the ERPM opportunity had been identified, it was agreed that the process development should be fast-tracked so that the ATFP could be included as part of the AMD treatment process. The specific aims of this project were:

- To incorporate the results from the ongoing laboratory work on the contact stabilisation reactor treating Grootvlei AMD at low Fe(II) concentrations and low pH.
- To define the operation of the contact stabilisation reactor for AMD containing higher Fe(II) concentrations.
- To operate a pilot scale ATFP treating Harmony Gold AMD using the process configuration used in the laboratory studies.
- To develop and optimise the ATFP at laboratory scale so that a more efficient, better engineered and more practical process could be developed.
- To incorporate these modifications into the existing pilot plant and again prove the process.

Several phases of experimentation were conducted, in which specific aspects of the integrated ATFP were investigated, so that specific engineering data could be obtained for each step of the process and converted into an optimised pilot plant design. The first phase was to determine the operating window for the contact stabilisation reactor treating Grootvlei AMD, where the ferrous iron concentration was relatively low ( $< 100$  mg Fe/L).

The results from this investigation indicated that there is a relationship between the operating pH, retention time, ferrite seed concentration and feed ferrous iron concentration in removing the ferrous iron from solution and forming ferrite intermediate on the ferrite seed present. The results showed that for a feed Fe(II) concentration of 100 mg Fe/L, the contact stabilisation reactor should be operated with a 30 minute retention time, a ferrite seed concentration of at least 2 g Fe/L and a pH of 7.5. For a feed Fe(II) concentration of 200 mg Fe/L, the contact stabilisation reactor required a 40-minute retention time and a ferrite seed concentration of 3.9 g Fe/L at a pH of 7.5. These results confirmed that the ATFP could be used to remove iron from Grootvlei AMD at lower operating pH, which is less detrimental to the receiving water body. The next stage was to operate the contact stabilisation reactor fed Harmony Gold AMD, which contained Fe(II) concentrations between 280 and 890 mg Fe/L. The results showed that the contact stabilisation reactor was capable of removing all of the aqueous ferrous iron from the AMD if the system was operated at a pH of at least 9. For the systems, the feed ferrous iron was removed from as high as 890 mg Fe/L with seed concentrations of 3 g Fe/L and retention times as low as 10 minutes, although 15 minutes was required for a system operating with a pH of 9. For solids removal, a clarifier operating with an up flow velocity of 5 m/h was required, resulting in 14 times thickening of the ferrite solids (seed plus intermediate).

When the ATFP pilot plant was operated under these conditions, the system failed within a few days, indicated by a build-up of brown-coloured material in the process. This result coincided with results obtained from the laboratory-scale experiments that were being conducted at the same time, where the production and accumulation of ferric-based products was observed. Further investigation showed that this was due to the source and quality of the ferrite seed being used in the process, and fresh ferrite was produced in the laboratory using a high-temperature process for the remaining experiments. Further laboratory tests showed that

the presence of magnesium in the ferrite intermediate tended to accumulate ferric in the ferrite intermediate, and this led to the brown colour witnessed before in failing experiments. Additional seed (from 20 to 60 g Fe/L) reduced the effects of the magnesium, resulting in lower ferric iron in the ferrite intermediate.

The pilot plant was operated again with the following changes:

- Freshly-produced ferrite seed was used instead of mined ferrite.
- The ferrite seed concentration in the oxidation reactor was to be maintained at 60 g Fe/L.
- The contact stabilisation reactor was operated with a pH of 9 and then 8.3 to lessen magnesium precipitation with the ferrite intermediate.
- A seed washing step was introduced where the ferrite intermediate was washed with potable water to remove soluble magnesium from solution and prevent this precipitation in the oxidation reactor.
- A seed prewashing step was introduced where the seed was contacted with the raw AMD so that the free acid in the AMD could dissolve the magnesium and ferric products that were accumulating in the ferrite intermediate.

The results from this pilot plant operation showed that it was difficult to maintain high seed concentrations in the system using the existing infrastructure, since the freshly produced ferrite seed had different settling properties to the mine ferrite. This led to a steady deterioration in the solids quality and ultimately process failure. Therefore, it was not possible to operate a successful ATFP treating AMD using lime. The process should first be proven at laboratory scale using AMD and lime before another pilot plant is built and operated. In light of the outcomes of this project, the recommendation would be for further research at laboratory scale with specific focus into the mechanism of ferrite formation under the conditions described for the ATFP. The research must be of high quality for capacity building and formulate models that describe the mechanisms of ferrite formation with respect to process parameters. Subsequent piloting would utilise these developments toward a goal of commercialisation.