The role of microorganisms in sulphide oxidation on Witwatersrand Gold Mines – and its inhibition at the source

J. Ravjee
Department of Geology, University of the Witwatersrand, PO WITS, 2050, Johannesburg, South Africa, and Economic Geology Research Unit, Geology Department, University of the Witwatersrand, PO WITS, 2050, Johannesburg, South Africa

R. H. Boer
W. U. Reimold
Department of Geology, University of the Witwatersrand, PO WITS, 2050, Johannesburg, South Africa

On average, a single Witwatersrand gold mine deposits approximately 1000 t of dissolved salts into the Vaal River per day. These salts are carried by what is generally termed acid mine drainage (AMD). It is generated in most areas of mining involving sulphide minerals – from underground working stopes to tailings deposition. The oxidation, by both chemical and biological processes, and leaching of sulphide minerals, when they are exposed to air and water, result in the formation of acidic drainage loaded with sulphate and toxic metals.

The rate of sulphide oxidation is largely dependent on the presence of bacteria, such as *Thiobacillus ferrooxidans, Thiobacillus thiooxidans,* and *Leptospirillum ferrooxidans,* which oxidize ferrous iron and/or reduced sulphur compounds (elemental sulphur and metal sulphides). Bacterially catalysed oxidation of pyrite (the most common sulphide associated with Witwatersrand gold mining) to produce AMD can be represented by the following stoichiometric equation:

$$2FeS_2 + 7.5O_2 + 7H_2O = 2Fe(OH)_3 + 4H_2SO_4$$

in which pyrite is oxidized to produce sulphuric acid and iron hydroxide (Shelp *et al.*, 1995). The continuous supply of service water and fresh pyritic ore, as well as the heat, in underground mining stopes provide ideal conditions for bacterial pyrite oxidation. Biooxidation is limited to microenvironments, defined by the surface of an individual sulphide grain. However, the cumulative effect is sufficient to generate a significant environmental problem.

Because of its increased acidity and metal concentration, AMD is detrimental to the aquatic ecosystem. Extensive remediation programs could become a financial liability to the mining-houses. Methods such as passive wetland treatment of AMD significantly decrease the acidity and metal content of the water, but tend to have a shorter than required life-span.

Prevention is the key to controlling AMD. Inhibition strategies range from the use of anionic detergents and organic acids to liming of operational mines and the hydraulic sealing of abandoned mines. Although many *in situ* inhibitory strategies are available, a suitable method employed to ameliorate AMD *at its source* would have to be practical for application in the underground environment. It should not interfere with the actual mining procedure and, more importantly, not have any adverse effects on the environment or the mining workforce.

The purpose of this experimental study is to determine the rate of sulphide oxidation on crystalline and buckshot pyrites by a mixture of the above-mentioned *Thiobacillus* and *Liptospirillum* bacteria species. The experiments are conducted at a temperature of 33°C and an initial pH of 2. The effect of inhibitory measures, such as the use of sodium chloride, citric acid, and ultra-violet light, to impede the bacterial sulphide oxidation process is also investigated. The results are compared to results from similar laboratory studies (Tuttle *et al.*, 1977; Lawson *et al.*, 1995; Adair, F.W., 1968; and Olson, G.J., 1991).

In addition to the preventative measures being tested, lab-scale experiments are being conducted on the treatment of acid mine drainage. Different carbon substrates (hay, sewage sludge, and mushroom compost) are tested to determine which substrate or combination of substrates would optimize the process of improving the water quality in a wetland plant. Acid mine water is passed through a series of bioreactors, each containing one of the above substrates. The parameters being monitored are change in pH, conductivity, alkalinity, and sulphate content of the effluent water compared to that of the original acid water. Anti-channeling measures are also investigated so as to increase the amount of water-substrate interaction and thereby improve the efficiency of the treatment plant.

References

Adair, F.W. (1968) *J. Bacteriol.*, **95**, 147–51.

Lawson, E.N., Nicholas, C.J. and Pellat, H. (1995) Biohydrometallurgical Processing Conference, 165-174, University of Chile.

Olson, G.J. (1991) *Appl. Environ. Microbiol.*, **57**, 642–4.

Shelp, G.S., Chesworth, W. and Spiers, G. (1995) *Appl. Geochem.*, **10**, 705–13.

Tuttle, J.H., Dugan, P.R. and Apel, W.A. (1997) *Appl. Environ. Microbiol,* **33**, 459–69.