

## TITLE PAGE

Phosphate stabilisation of partly oxidised,  
polyminerallic mine wastes.

Thesis submitted by

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Chapter two of this thesis is based on the scientific paper Harris, D.L., Lottermoser, B.G and Duchesne, J. 2003 Ephemeral acid mine drainage at the Montalbion silver mine, north Queensland: Australian Journal of Earth Sciences (in press). Significant contributions were made to this chapter by Dr. Bernd Lottermoser (JCU) and Dr. J Duchesne (Laval University).

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## Abstract

The oxidation of sulphides present in mine waste may produce acidity and release dissolved metals and sulphate into local surface and ground waters. This process is known as acid mine drainage and is considered the most important environmental problem currently facing the mining industry. Phosphate induced stabilisation has been used to create passive iron phosphate coatings on pyrite and pyrrhotite. The formation of solid phosphate coatings on the sulphide grains thereby inhibits sulphide oxidation. The aims of this study were to determine whether the phosphate stabilisation technique would inhibit acid generation and attenuate metals released from partly oxidised, polyminerallic mine waste (obtained from the Montalbion Silver mine, north Queensland) under laboratory conditions.

Sulphide-rich materials comprising the waste at the abandoned Montalbion silver mine have undergone extensive oxidation prior to and post mining. Weathering has led to the development of an abundant and varied secondary mineral assemblage throughout the waste material. Post-mining minerals are dominantly metal and/or alkali (hydrous) sulphates and generally occur as earthy encrustations or floury dustings on the surface of other mineral grains. The variable solubility of these efflorescences, combined with the irregular rainfall, controls the chemistry of seepage waters emanating from the waste dumps. Irregular rainfall events dissolve the soluble efflorescences which have built up during dry periods, resulting in 'first flush' acid (pH 2.6–3.8) waters with elevated sulphate, Fe, Cu and Zn contents. Less soluble efflorescences, such

as anglesite and plumbojarosite, retain Pb in the waste dump. Metal-rich (Al, Cd, Co, Cu, Fe, Mn, Ni, Zn) acid mine drainage waters enter the local creek system. Oxygenation and hydrolysis of Fe lead to the formation of Fe-rich precipitates (schwertmannite, goethite, amorphous Fe compounds) which, through adsorption and coprecipitation, preferentially incorporate As, Sb and In. Furthermore, during dry periods evaporative precipitation of hydrous alkali and metal sulphate efflorescences occurs on the perimeter of stagnant pools. Flushing of the streambed by neutral pH waters during heavy rainfall events dissolves the efflorescences resulting in remobilisation and transportation of sulphate and metals (particularly Cd, Zn) downstream. Thus, in areas of seasonal or irregular rainfall, secondary efflorescent minerals present in waste materials or drainage channels have an important influence on the chemistry of surface waters.

Waste materials for the phosphate stabilisation experiments were sourced from the Montalbion silver mine. Three kinetic column leaching experiments were conducted using (a) polyminerallic unoxidised sulphidic mine waste and liquid phosphate stabiliser, (b) partly oxidised polyminerallic mine waste and liquid phosphate stabiliser, and (c) partly oxidised polyminerallic mine waste using liquid and solid phosphate fertilisers. SEM observations of the treated waste material showed that phosphate coatings and precipitates formed in all experiments. Metal-alkali phosphate coatings formed on all sulphides when  $\text{KMnO}_4$  and phosphate fertilisers were used in the coating solutions. Otherwise tetrahedrite was uncoated. The phosphate coatings were most abundant on chalcopyrite and were interpreted to be chemically connected with the

underlying sulphide. In contrast, the metal, metal-alkali and alkali phosphate precipitates were interpreted to be physically connected to their substrates. The abundance of phosphate development appeared to be dependent on the abundance of cations in solution available for precipitation with the phosphate anions. The release of cations was predominantly dependent on oxidant strength, through sacrificial sulphide oxidation, or the dissolution of soluble sulphate minerals present in the partly oxidised waste.

Leaching of the coated material in a strongly oxidising solution showed that the phosphate coatings and precipitates inhibited acid generation and probably inhibited metal release in all experiments. Thus, the phosphate coatings prevented oxidant access to the sulphide surfaces, inhibiting sulphide oxidation. Lead and Fe phosphates were the most stable in the oxidising solution, whereas Cu and Zn phosphates were partially dissolved. Arsenic and Sb were mobilised by the coating process due to the higher mobility of these metalloids at circum-neutral pH.

The results of this study demonstrate that phosphate stabilisation can suppress sulphide oxidation and metal release in partly oxidised, polyminerallic mine wastes on a laboratory scale.



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