1 Introduction

The oxidation of sulphidic mine wastes, and the consequent release of acid drainage is one of the main strategic environmental issues facing the mining industry. The production of broken waste rock and tailings by mining operations can expose large amounts of pyrite and other sulphides to the effects of water and oxygen. The oxidation of sulphides in rock is a natural process which normally occurs slowly as the surface of the earth erodes and the underlying rock oxidises. Mining operations can greatly accelerate the oxidation process by providing flow paths that allow the release of levels of pollutants in surface and ground water at rates far greater than the downstream environment can sustain without significant ecological effects.

For this study, the term *acid mine drainage* is used to include all processes whereby the inadvertent oxidation of sulphides following mining leads to the release of pollutants. This includes seepages from waste rock, tailings, underground workings and pit walls where the contaminants are produced by the oxidation of sulphides. It also includes the release of pollutants even if subsequent processes along the flow path neutralise the acidity but leave excessive levels of heavy metals in water. Quarrying operations were excluded from the study.

Australia has a number of historic closed mines where acid mine drainage caused and, in many cases, still causes major pollution problems. Rehabilitation projects have been undertaken at the Rum Jungle mine site in the Northern Territory, Captains Flat mine site in New South Wales and Brukunga in South Australia. Other well known sites where acid drainage is a major problem are the Mt Lyell mine in Tasmania and the Mt Morgan mine in Queensland. There are also many less well known historic sites that continue to suffer from the effects of acid mine drainage.

Once started, the release of pollutants from the oxidation of sulphides is a persistent and potentially severe source of pollution from mine sites. It is the long-term nature of acid mine drainage which creates the environmental problems for mine operators. During mine operations, treatment of polluted surface waters is usually a minor addition to mining costs. However, acid drainage can continue to be a major source of pollution long after mining ceases.

Acid mine and acid rock drainage can cause major long-term environmental problems at many types of mine sites if appropriate management strategies are not adopted. Acid mine drainage is a potential problem at many base metal mines where recoverable metals occur as metal sulphides, at some coal mines where pyritic coal seams are mined and at some uranium and gold mines where the ore is associated with sulphidic materials. The ubiquitous nature of pyrite in many valuable mineral deposits means that control of sulphide oxidation is important if mine owners are to avoid long-term liabilities when the site is released at the end of mining.

The Australian Mining Industry Council (AMIC) Environment Committee Report on Research Priorities and Needs (1994) identified acid drainage as one of the main strategic environmental issues facing the mining industry. Miller (1992) found for the Australia mining industry as a whole that 30 to 40% of mine waste samples he had received for analysis were potentially acid generating.

Despite general agreement on the importance of acid mine drainage at Australian mine sites, its extent has not been quantified and the additional costs of managing acid mine drainage have not been estimated. This information was needed to provide a basis for assessing the priorities for future research and development into the management of potentially acid generating mine wastes and the control of acid mine drainage in Australia.

1.1 OSS/ACMRR study of acid mine drainage in Australia

In order to better understand the impact of acid drainage in Australia and to provide a basis for assessing long-term management options, the Office of the Supervising Scientist (OSS) and the Australian Centre for Minesite Rehabilitation Research (ACMRR) initiated this study to prepare a status report on acid mine drainage in Australia. The study is supported by the Minerals Council of Australia (see copy of letter dated 23 May 1996 from David Buckingham, Executive Director Minerals Council of Australia in Appendix C1).

The coverage of this study includes all mine sites where sulphidic oxidation in mine wastes or mine workings leads to the release of contaminated drainage with off-site impacts.

The objectives of the study are:

- to quantify and characterise the generation of contaminated drainage by sulphidic oxidation from historic and current mining activities in Australia;
- to develop a classification scheme to characterise the potential for off-site impacts from sulphidic oxidation in mine wastes;
- to compare the cost at the national level of managing sulphidic oxidation in mine wastes and any resulting contaminated drainage with other mining and environmental costs;
- to make recommendations based on the information received to improve the understanding and management of acid mine drainage in Australia.

Information was collected on the extent and management of sulphidic oxidation and acid drainage at operating, historic and derelict mines in Australia. Mining operators, environmental officers, industry representatives, state government departments and others were asked about their experience with acid mine drainage and how it is currently managed at operating and historic mine sites.

2 Background

2.1 Pyrite oxidation

The release of acid mine/rock drainage is due to the oxidation of pyrite and other sulphides in mine wastes and mine workings. The pyrite oxidation process will be briefly described to provide a basis for the discussion on the strategies used to control the oxidation of pyrite and the release of polluted waters. The oxidation of pyrite occurs when the mineral is exposed to air and water. At mine sites, this can occur in tailings dams, waste rock dumps, pit walls and in underground workings.

The pyrite oxidation process is complex and involves several chemical, biological and electrochemical reactions. The rate of reaction depends on many factors including the surface morphology of pyrite, the oxygen concentration, the pH, the presence of bacteria and the presence of acid-consuming materials. The oxidation process has been extensively studied under laboratory conditions, and more detailed descriptions of the steps and complexities of the oxidation process are available in the literature (eg Evangelou 1995, Hutchinson & Ellison 1992).