

# Impact of Iron Duke Pyrite Mine on water chemistry and aquatic life – Mazowe Valley, Zimbabwe

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## Abstract

Iron Duke Mine is the only active pyrite mine in Zimbabwe, and has been in operation since the 1940s. Its location in the multiple-use upper catchment of the Mazowe Valley is strategic in terms of water resource management. The mine disposes of its highly acidic wastewater into two evaporation ponds on the north-eastern side of the mine. This has led to acidification of the groundwater to a pH of about 2 near the evaporation ponds as well as contamination with Fe, Ni, Cu, Co, Pb, Zn and  $\text{SO}_4^{2-}$ . The pH gradually increases in a north-westerly direction, but much faster towards the west and south-west. Water samples taken from the Yellow Jacket River, which runs through the mine premises, indicated that the upper part of the river was not contaminated with Fe, Ni, Cu, Co, Pb, Zn or  $\text{SO}_4^{2-}$  and had a neutral pH. However, where the river cuts through gossans and passes adjacent to the mine waste dump and the seepage zone from the evaporation ponds, the water quality deteriorates. The symptoms are a reduction in pH of river water from 7 to about 4 and the precipitation of complex iron hydroxy-sulphates known as “yellow boy” on the streambed. Fe, Ni, Cu, Co, Pb, and Zn concentrations are also elevated here. This poor water quality persisted downstream until the confluence with the Mazowe River where the acidic waters were diluted, and the pH returned to 7. The poor water quality in the Yellow Jacket River is related to an overall reduction in the diversity of aquatic macro-invertebrates and fish downstream of the mine until the confluence with the Mazowe River.

**Keywords:** water chemistry, water pollution, acid mine drainage, aquatic ecosystems

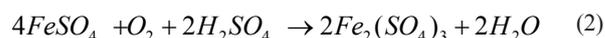
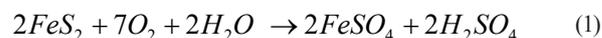
## Introduction

### Mining and acid mine drainage

The majority of materials and metals extracted from the Earth by mining occur naturally as sulphide ores or are associated with sulphide minerals. During the extraction process, those sulphides which are not part of the ore material are dumped in waste rock dumps with other rocks. Sulphides containing valuable material (either metals, or in the case of a pyrite mine, sulphide itself) are processed, and the residue dumped in slimes (tailings) dams. The tailings contain large amounts of sulphide, which are either unwanted or were not extracted (Lupankwa et al., 2004a). This results in more of the sulphides being exposed to the surface environment, where they are unstable. Thus spontaneous chemical weathering takes place, releasing acid, metals and sulphate into surface water and groundwater (Bigham and Nordstrom, 2000). This process, whereby sulphide minerals break down in the presence or oxygen and catalysing bacteria, is known as acid mine drainage (AMD).

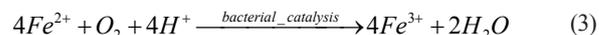
Pyrite (iron sulphide) is the most abundant sulphide and the major sulphide at the mine studied in this paper. It breaks down in the presence of oxygen and water to form iron (II) sulphate

and sulphuric acid (Eq. (1)) and ultimately iron (III) sulphate (Eq. (2)):



Certain chemolithotrophic bacteria, notably *Thiobacillus thiooxidans*, *Thiomicrospira* sp. (Knickerbocker et al., 2000), but also *Thiobacillus ferrooxidans* to a limited extent (Benner et al., 2000), use pyrite as an energy source for  $\text{CO}_2$  fixation and cellular metabolism, and thus can catalyse sulphide oxidation (Eq. (1)). Such bacteria are common in sulphide tailings.

However, the major role of bacteria such as *T. ferrooxidans* and *Leptospirillum ferrooxidans*, is in catalysing the oxidation of iron (II) to iron (III) (Benner et al., 2000; Kelly, 1988):



*T. ferrooxidans* and similar bacteria have been found in water draining from various mine waste deposits, in soil and in the vadose zone below the same deposits (Benner et al., 2000; Loos et al., 1990), as well as in streams draining mine dumps (Kelly, 1988). The bacteria can also function underground in a flooded mine (Bond et al., 2000). Such bacteria thrive in low pH environments - indeed the *Thermoplasmales* have been shown to grow at  $\text{pH} < 0.5$  (Edwards et al., 2000a).

According to comparisons of abiotic laboratory tests with field studies of sites with known *Thiobacillus* presence (Kirby

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