LABORATORY STUDY OF SUBMERGED METAL-MINE TAILINGS 1: EFFECT OF SOLID-LIQUID CONTACT TIME AND AERATION ON CONTAMINANT CONCENTRATIONS

by

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ABSTRACT

The dissolution of metals from various metal-mine tailings has been studied through a series of submerged tailings batch tests at U.S. Bureau of Mines laboratories. Tailings selected for this study included both reactive (as determined by column leaching studies) and benign tailings. Metal mobilization in aerated (97 pct saturated with oxygen) samples appeared to be consistently greater than metal dissolution from stagnant (79 pct or 70 pct saturated with oxygen) waters. In the early weeks of the study, sulfate concentrations increased with solid-liquid contact time, while calcium dissolution remained nearly constant. Metal concentrations varied in relation to solid-liquid contact time and aeration. Leachate pH appeared to be nearly independent of solid-liquid contact time for basic tailings. Reactive tailings having both a submerged and a surface component demonstrated increased metal mobility.

INTRODUCTION

During mining operations, minerals are exposed to oxidizing environments that accelerate weathering. The oxidation of iron disulfides, in particular marcasite and pyrite, is a major cause of acid mine drainage (Caruccio et al., 1977; Potter and Nordstrom, 1977), which is initiated either by simple dissociation of iron pyrite or by the oxidation of pyrite (Singer and Stumm, 1970). In a sulfate and iron-rich acidic solution having a pH of about 3, the oxidation of ferrous iron is extremely slow, whereas the oxidation of pyrite by ferric ion is rapid. Once this propagation cycle is in motion, the initiation reaction is no longer significant (Singer and Stumm, 1968).

Another factor that affects the rate of acid formation is a group of bacteria that includes Thiobacillus ferrooxidans, Ferrobacillus ferrooxidans, and other related species (Silverman, 1967). T. ferrooxidans was significant in acid formation in soil samples having a plentiful supply of oxygen and water, but it had little effect on acid production in soils where oxygen was limited (Kleinmann et al., 1978).
Previous investigations (Doepker, 1988; Doepker, 1989) reported that enhanced metal dissolution was not apparent in water-saturated tailings where solid-liquid contact times extended over 2 to 3 months, presumably because oxidation is so slow. Case studies, such as those in Shasta County, CA (Potter and Nordstrom, 1977; Nordstrom, 1985), point to major oxidation in the capillary zone of tailings impoundments and, to a much lesser extent, in the submerged tailings found in the creeks of the area (Fillpek et al., 1987). Similar results were found during a study at Elliot Lake, Ontario (Dave et al., 1986).

The purpose of the present study is to examine those parameters that influence metal dissolution from submerged tailings, particularly contact time and aeration.

MATERIALS AND METHODS

Tailings from two lead mines and a copper mine were selected for this initial study. Both lead mine tailings were composed essentially of dolomite \([\text{CaMg(CO}_3\text{)}_2]\) with trace amounts of sphalerite (ZnS), pyrite (FeS2), galena (PbS), microcline (KAlSi3O8), and cristobalite (SiO2). The mineral analysis of lead mine A tailings showed that the pyrite grains were of uniform size and ranged from 5 to 25 micrometers in diameter. Cubic galena crystals were generally smaller than crystals of the other sulfide minerals in the sample and averaged 2 to 3 micrometers in cross section. The pyrite and sphalerite were 90-pct liberated; the galena was 70-pct liberated. A similar mineral characterization for lead mine B tailings is not available at this time. The abbreviated results of the "maximum leachability assay" (a nondestructive, mixed HCl-\text{HNO}_3 assay) (Kuryk et al., 1985) for tailings from lead mines A and B and copper mine A are given in Table 1.

Copper mine A tailings contained abundant free pyrite, and grain size ranged from 20 to 50 micrometers. Magnetite (Fe3O4) and ilmenite (FeTiO3) were present in relatively significant amounts. Chalcopyrite (CuFeS2) occurred in minor amounts, usually locked with gangue particles. Gangue was predominantly quartz (SiO2) and orthoclase (KAlSi3O8). Several other minerals identified in the sample included pyromorphite [(PbCl)Pb4(P04)3]; an iron-zinc silicate, POSSIBLY danalite; and a lead-copper-antimony phase identified as either bournonite (PbCuSbS3) or a lead-bearing tetrahedrite (3Cu2S:Sb2S3), which occurred as inclusions in the iron-zinc silicate.

The tailings samples used in this study were air dried in the laboratory and crushed to the original size range, mixed well, and stored in plastic containers.

Chemicals

All chemicals in this study were commercially available, analyticalgrade reagents used without further purification. The deionized water was produced in the laboratory through distillation (Barnstead glass still) and then deionized with a Barnstead NANOpure II Demineralizer (18.3 Mohm/cm).

Batch Test Equipment and Method

In one series, 2 kg of lead mine A tailings were slurried with 2 L of deionized water and poured into a 4-L, wide-mouth, polyethylene bottle. An additional 1.5 L of deionized water was added to each of seven identical samples, yielding a solid-to-liquid ratio of 0.57. Three bottles were equipped with fish-tank aeration systems, three were loosely covered with perforated plastic wrap, and one was capped. Fifty-cubic-centimeter solution samples (for analyses) were taken at