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Densification of iron(III) sludge in neutralization

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Abstract

Acid mine drainage (AMD), of which iron is a substantial component, is a potential by-product in the mining industry. Conventional neutralization is a common approach to treat AMD, although it creates a major disposal problem due to the generation of voluminous sludge. Sludge recirculation improves solid density by slowing down the rate of neutralization and allowing the growth of precipitates, while existing solids act as seed particles by providing necessary surface area for precipitation. The mechanisms of iron sludge densification are not fully understood, mainly because of the complex nature of iron chemistry, and the variety of amorphous, polymeric oxides that could be formed. In this work, the effects of alkaline reagents, flocculant addition, and dosing sequence, on the precipitation of iron (III) hydroxide and densification of the recycled sludge were investigated. Slowly dissolving lime ($Ca(OH)_2$) was found to be more effective than caustic (NaOH) in producing sludge with higher solid contents. Polymers addition created stronger aggregates that could withstand shearing without significant size reduction, but the overall sludge density was lower than those produced without flocculant. Conditioning the sludge at pH between 3.5 and 4.5 by adding fresh lime in a specific dosing manner appeared to be conducive to the growth of large agglomerates. The final sludge solid content of ~15 wt.% was considerably higher than others produced under different conditions. The plate-like structures of precipitates generated with more recycles in this instance, possibly helped ease the release of entrapped water between solids during shearing, thus producing sludge with higher solid density.

Keywords: neutralization; iron hydroxide; precipitation; pH; sludge recycle; densification

1. Introduction

Iron is one of the most abundant metals found in a variety of ores with other elements. Iron pyrite (FeS_2) is a sulfide-containing compound often uncovered during a mining process. The pyrite oxidizes upon contact with air and water, and reacts

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to form ferric hydroxide precipitant and sulfuric acid (Silver, 1993)

$$FeS_2 + 15/4O_2 + 7/2H_2O \rightarrow 2H_2SO_4 + Fe(OH)_3 \quad (1)$$

The products, also known as acid mine drainage (AMD), are detrimental to the environment. Conventional neutralization of AMD involves increasing the pH of the waste streams to a specific value, depending on which metals are to be removed. For AMD with a ferrous iron component, air is frequently injected for oxidation, producing a more chemically stable ferric iron sludge. The process often creates a voluminous sludge with solids concentration as low as 1%, particularly when treating effluents with low solid loadings (Fig. 1(a)).

Chemicals that are ordinarily used to neutralize AMD include lime ($Ca(OH)_2$), limestone ($CaCO_3$), hydroxides ($Mg(OH)_2$, NaOH), sulfides (Na_2S, NaHS, CaS), and ammonia (NH_3). Lime is the traditional choice in industry due to its high pH value, requiring only a reasonable reaction time for simultaneous formation of metal hydroxides and calcium sulfate (gypsum)

$$Ca(OH)_2 + M^{2+}/M^{3+}H_2O + H_2SO_4 \rightarrow M(OH)_2/M(OH)_3 + CaSO_4 + H_2O \quad (2)$$

To increase the sludge solid content, a sludge recycle process (Fig. 1(b)), known as the High Density Sludge (HDS) process, was invented (Kostenbader and Haines, 1970). The process is thought to remove free water molecules by altering particle structures or by forming precipitates with fewer water molecules per solid particle; giving a more compact, hydrophobic sludge. The geochemical stability of the precipitates is also favored when there is a high iron to total metals ratio in the plant feed. The sludge solid content (around 10–30%) is generally much higher than a conventional neutralization process (Kuyucak, 1998). The initial work indicated that the process

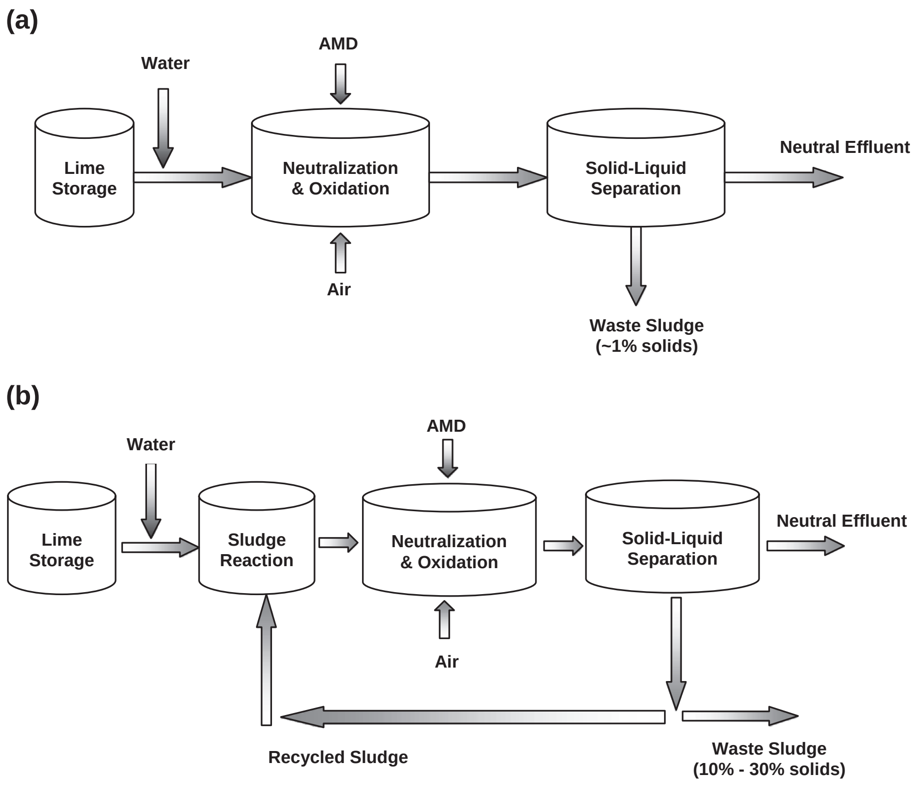

Fig. 1. Schematics of (a) conventional neutralization and (b) neutralization with recycle (or High Density Sludge process).