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The dissolution kinetics of atacamite in the acid range and the stability of atacamite containing soils from Namaqualand, South Africa

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ABSTRACT

The Cu hydroxy mineral, atacamite, is commonly associated with saline environments and is generally thought to dissolve rapidly in the presence of fresh water. A Cu contaminated soil from the arid Namaqualand region, South Africa, shows atacamite as the dominant Cu containing mineral. The stability of the Cu phase in this soil was determined through equilibrium and leaching studies using both deionised water (DI) and a concentrated (0.5 M) NaCl solution. Initially a high concentration of exchangeable Cu was released from the soils leached with NaCl. Continued leaching with NaCl resulted in a substantial decrease in Cu release as atacamite equilibria started to control dissolved Cu. This suggests that an initial spike of Cu laden water will leach from the soils at the onset of a large rainfall event. Further additions of water will result in a lower but sustained release of Cu from the soil. The Cu contaminated soils are exposed to acidic sulphate leachate thus the dissolution kinetics of synthetic atacamite in the acidic range (pH 5.5–4.0) was determined in both NaCl and DI solutions. The kinetic data showed that atacamite dissolution rates are significantly higher in DI than in NaCl but the rates converge at pH 4. In comparison to common acid soluble minerals, atacamite displays a moderate dissolution rate ($10^{-9.55}$–$10^{-7.14}$ mol m^{-2} s^{-1}) within the acid range (pH 5.5–4.0). The atacamite dissolution reaction order with respect to pH is 1.3 and 1.6 in DI and NaCl solutions, respectively, suggesting that dissolution rates of atacamite are highly pH dependent in the acid range. The type of acid used to lower the pH had no effect on the reaction kinetics, with HNO_3 and H_2SO_4 resulting in comparable dissolution rates of atacamite at pH 4.5.

1. Introduction

The Cu hydroxy mineral, atacamite [$Cu_2(OH)_3Cl$], occurs commonly in the oxidised zones of porphyry Cu deposits in the Atacama desert (Cameron et al., 2007; Reich et al., 2009; Sillitoe, 2005). It has also been observed in deep seafloor vents (Hannington, 1993), as a corrosion product of Cu-containing metals in coastal environments (Livingston, 1991) and in saline soils contaminated with Cu-bearing mine leachate (Clarke et al., 2014). Atacamite (used collectively hereafter to represent both atacamite and paratacamite) is a basic Cu hydroxide and is usually formed under neutral to alkaline conditions (Sharkey and Lewin, 1971) in high Cl environments (Woods and Garrels, 1986). Due to the high Cl requirement for the formation of atacamite, it is often regarded as unstable when exposed to fresh or low salinity solutions as Cu hydroxy minerals react rapidly to changes in their environment (Woods and Garrels, 1986).

Numerous studies, proposing the formation conditions of the atacamite deposits in Northern Chile, have highlighted the rapid dissolution and instability of atacamite in the presence of meteoric water (Cameron et al., 2007; Reich et al., 2008, 2009). However, the kinetics of atacamite dissolution in saline and non-saline waters have not been previously quantified. MacFarlane et al. (2005), included an atacamite containing ore material in their demonstration of a continuous leaching system. They observed that the majority of Cu was released from the ore during the initial water leach; however, the ore contained numerous Cu phases and thus direct information on atacamite dissolution was obscured. Most Cu hydroxy mineral dissolution studies are directed at ore processing techniques (Bingöl and Canbazoğlu, 2004; Quast, 2000). In these

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