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Effect of lactate, glycine, and citrate on the kinetics of montmorillonite dissolution

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Abstract

The montmorillonite dissolution in saline solutions that mimic synthetic lung fluids (SLF) was investigated to gain knowledge on the clearance mechanisms of inhaled clay particles. Dissolution rates were measured at pH 4 (macrophages) and 7.5 (interstitial fluids) at 37 °C in flow-through reactors. The effect of organic acids was investigated through the addition of lactate, citrate, and glycine (0.15, 1.5, and 15 mmol/L). Lactate or glycine does not markedly affect the montmorillonite dissolution rates at pH 4, but at pH 7.5 there exists a slight inhibitory effect of lactate on the dissolution, probably due to a reduction in the number of reactive surface sites caused by lactate adsorption. Citrate enhances the dissolution rate by 0.5 order of magnitude at pH 4 and more than 1 order of magnitude at pH 7.5, thus indicating the prevalence of the ligand-promoted over the proton-promoted dissolution mechanism under these experimental conditions. The kinetic data were used to estimate the reduction in size of an inhaled clay particle. At pH 7.5, a particle 500 nm in diameter could be reduced 25% in the presence of citrate, whereas the reduction in saline solution would only be 10% after 10 years.

Ligand adsorption was measured in batch experiments at pH 2–11 and EQ3NR was used to model the capacity of the ligands to form soluble species of Al. Citrate, glycine, and lactate adsorb onto montmorillonite under acidic conditions, up to 23, 26, and 60 μmol/g, respectively. However, only citrate can complex the released aqueous Al at pH 4 and 7.5, which contributes to enhance dissolution rate and prevents precipitation of gibbsite at pH 7.5.

The enhancement of the dissolution rate in acidic citrate solution very likely comes from the formation of surface complexes between the ligand and the edge surface of montmorillonite. In neutral conditions the effect may be also due to the decrease of the activity of Al^{3+} by formation of aqueous Al-citrate complexes.

Keywords: Montmorillonite, dissolution rate, organic ligands, adsorption