A high-capacity aluminum hydroxide-based adsorbent for water defluoridation

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ABSTRACT

In this study, the properties and fluoride-uptake capacity of aluminum hydroxide-based (AO) adsorbent has been investigated. AO was synthesized, characterized, and tested in batch and column experiments. The surface area of the AO was found to be 37.7 m² g⁻¹. The composition was determined to be 90% Al(OH)₂₈SO₄₀₁ (or 78.3% Al(OH)₃ plus 10.7% Al₂(SO₄)₃) with 10% Na₂SO₄ (as an impurity). The material is X-ray amorphous and scanning electron microscopic (SEM) studies show AO to be a network of fibers with a size range of 200–300 nm. Fluoride uptake was found to be unaffected by sodium salts of chloride and sulfate in concentrations up to 500 mg/L. A reduction of fluoride uptake with increasing concentrations of hydroxide and bicarbonate was ascribed to the pH dependence of fluoride sorption, while phosphate appeared to compete with fluoride for sorption sites. The surface site concentration determined by acid–base titrations is 0.5 meq/g (equivalent to a surface site concentration of 8 sites/nm²) and an acidic component of 1.4 meq/g. Continuous packed column experiments showed that at a flow rate of 100 empty bed volumes (eBV) per day using deionized water, the fluoride uptake capacity was 26.2 mg F/g. The pH of treated water ranged between 4.4 and 7.0. In solutions representing buffering conditions of Ethiopian groundwaters (pH 8 ± 0.2, 10 mM NaHCO₃, 3,000 ppm CO₂) uptake capacities at 100 and 10 eBV/day were 4.65 and 9.0 mg F/g, respectively. Aluminum was initially released in concentrations ranging from 0.6 to 2.0 mg/L in solutions when the pH is less than 5. Initial salt concentrations were in the g/L range. With the introduction of calcite postcolumn treatment, the pH was maintained in the range of 7.5–8.5, which significantly reduced salt concentrations due to gypsum precipitation and prevention of early aluminum release were achieved. Due to its high uptake capacity compared with all commercially available adsorbents for fluoride removal, AO is a highly promising material for water defluoridation both at household and community levels.

Keywords: Fluoride; Adsorption; Aluminum hydroxide; Defluoridation; Ethiopia

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