Toxicological & Environmental Chemistry

Defluoridation of drinking water using Al3+-modified bentonite clay: optimization of fluoride adsorption conditions

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Abstract

Al^{3+}-bentonite clay (Alum-bent) was prepared by ion exchange of base cations on the matrices of bentonite clay. Intercalation of bentonite clay with Al^{3+} was performed in batch experiments. Parameters optimized include time, dosage, and Al^{3+} concentration. Physicochemical characterization of raw and modified bentonite clay was done by X-ray fluorescence, X-ray diffraction, energy dispersive X-ray spectrometry attached to scanning electron microscopy, Brunauer–Emmett–Teller analysis, cation exchange capacity (CEC) by ammonium acetate method, and pH(subpzc) by solid addition method. Chemical constituents of water were determined by atomic absorption spectrometry (AAS), ion selective electrode (Crison 6955 Fluoride selective electrode) and a Crison multimeter probe. For fluoride removal, the effect of contact time, adsorbent dosage, adsorbate concentration, and pH were evaluated in batch procedures. The adsorption capacity of fluoride by modified bentonite clay was observed to be 5.7 mg g^{-1} at (26 ± 2) °C room temperature. Maximum adsorption of fluoride was optimum at 30 min, 1 g of dosage, 60 mg L-1 of adsorbate concentration, pH 2–12, and 1:100 solid/liquid (S/L) ratios. Kinetic studies revealed that fluoride adsorption fitted well to pseudo-second-order model than pseudo first order. Adsorption data fitted well to both the Langmuir and Freundlich adsorption isotherms, hence, confirming monolayer and multilayer adsorption. Alum-bent showed good stability in removing fluoride from ground water to below the prescribed limit as stipulated by World Health Organization. As such, it can be concluded that Alum-bent is a potential defluoridation adsorbent which can be applied in fabrication of point of use devices for defluoridation of fluoride-rich water in rural areas of South Africa and other developing countries. Based on that, this comparative study proves that Alum-bent is a promising adsorbent with a high adsorption capacity for fluoride and can be a substitute for conventional defluoridation methods.