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Synthesis, characterization and performance evaluation of iron(III) oxide coated bentonite clay – silica rich reddish black Mukondeni clay soils composites for the defluoridation of groundwater

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ABSTRACT

Clay materials have been proposed as adsorbent mediums to remove fluoride from groundwater. This study investigated the removal of fluoride from aqueous solutions by newly synthesised iron(III) oxide coated bentonite clay, locally available silica rich reddish black Mukondeni clay soils and their ceramic composite. Raw bentonite clay was first activated by NaOH to remove geological fluoride in bentonite clay and thereafter coated with iron(III) oxides whereas silica rich reddish black Mukondeni clay soils were used raw. Physicochemical and mineralogical characterisation was done by X-Ray Fluorescence (XRF), X – Ray Diffraction (XRD), Scanning Electron Microscopy (SEM), Scanning Electron Microscopy - Energy Dispersive Spectroscopy (SEM-EDS), Fourier Transform Infrared (FTIR), Transmission Electron Microscopy (TEM) and Brunauer Emmet Teller (BET). Cation Exchange Capacity (CEC) and Point of Zero Charge (PZC) were determined using standard methods. Results showed that both clay soils are alumina silicate materials and quartz was the major mineral phase in the clays. BET showed that iron(III) oxide coated bentonite clay has a surface area of 132.3018 m^2/g whereas silica rich reddish black Mukondeni clay soils have a surface area of 43.2077 m^2/g. A batch fluoride sorption scheme was applied to evaluate their fluoride adsorption capacities and the system variables investigated included, initial sorbate concentration, agitation time, adsorbent dose, co-existing ions, pH and temperature. A maximum fluoride removal capacity of 1.596 mg/g was recorded for iron (III) oxide coated bentonite clay, which was higher compared to 0.08 mg/g of the silica rich reddish black Mukondeni clay soils and even much higher compared to that of the composite ceramic pellets (0.03 mg/g). It was also observed that the iron(III) oxide coated bentonite clay worked effectively over a wide range of pH (2 – 12) but the maximum fluoride removal was at pH 2. Between the pH range of 6 and 9 the fluoride removal capacity was above 70% and the material exhibited minimal metal leaching. On the contrary silica rich reddish black Mukondeni clay soils worked effectively only at pH 2 but exhibited minimal metal leaching across all tested pHs. The experimental data fitted well to the Freundlich isotherm for both clay soils which showed that adsorption took place on a multilayer surface. The adsorption kinetics fitted the pseudo second order model indicating chemisorption and the rate kinetics were regulated by external and internal diffusion for both clay soils. The high adsorption capacity of iron(III) oxide-coated bentonite clay indicated the potential use of this adsorbent for fluoride removal from aqueous medium whereas the low adsorption capacity of the silica rich reddish black Mukondeni clay soils and the composite ceramic pellets can be

enhanced by metal modification which has been shown to increase the adsorption of different clay soils.

Keywords: Adsorption isotherms, kinetics, thermodynamics, mechanisms, bentonite clay, Mukondeni clay soils, composite ceramic pellets and fluoride.