Characterisation of selected South African clays for defluoridation of natural waters

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Abstract

In large parts of South Africa groundwater contains excessive fluoride. In many such areas fluorosis is a serious problem among the local population. One way of solving the problem is to use simple house-based defluoridation systems using suitable clays, processed in various ways, as adsorbents. No information on the fluoride removal capacity of South African clays and soils is currently available. This study assesses the fluoride adsorption characteristics of clays selected from areas, such as the western Bushveld, where high fluoride concentrations in groundwater is a problem. Bauxitic clays were found to have the best overall potential as fluoride adsorbents. South African bauxite deposits, however, are not only low grade but are also to be found far from the problem areas in the North-West Province. Simple chemical activation using 1% Na_2CO_3 solutions and dilute hydrochloric acid could enhance adsorption capacity of certain clay types.

Keywords: defluoriation, fluorosis, fluoride adsorption, South African clay

Introduction

The occurence of high fluoride concentrations in groundwaters and the risk of fluorosis associated with using such water for human consumption is a problem faced by many countries, notably India, Sri Lanka, China, the Rift Valley countries in East Africa, Turkey, and parts of South Africa. Fluorosis is a debilitating disease caused by drinking water with fluoride concentrations higher than ca. 1 mg·ℓ$^{-1}$ for extended periods. The disease is characterised by mottled teeth in dental fluorosis and brittle bones in severe skeletal fluorosis. Much research has been carried out during the last 20 years to find cost-effective and practical solutions for the removal of excess fluoride from groundwater. In a recent report McCaffrey and Willis (2001) discussed the fluoride geochemistry of the North-West Province, one of the areas in South Africa where fluorosis is a problem. They focused attention on a serious problem faced by many rural communities which depend on borehole water with a high fluoride content for their drinking-water requirements. Affected areas include large parts of the Karoo, the Northern Cape, Limpopo, and North-West provinces. More than 30% of the ca. 3 000 boreholes in the Pilanesberg and western Bushveld area have fluoride concentrations > 1 mg·ℓ$^{-1}$. In alkaline waters (pH > 9) fluoride concentrations up to 30 mg·ℓ$^{-1}$ were recorded. The seriousness of the problem is exacerbated by evidence for a much lower safe maximum fluoride level in hot dry areas where the daily intake of water is much higher than normal. Brouwer et al. (1988) estimated that the maximum safe fluoride level in hot dry areas should be < 0.6 mg·ℓ$^{-1}$. This value is confirmed by an empirical formula developed by Foss and Pittman (1986), which can be used to estimate safe limits for drinking water as a function of average temperature. At an average temperature of 28.5°C, typical for the North-West Province, the equation estimates a threshold fluoride concentration of 0.6 mg·ℓ$^{-1}$, a value much lower than the 1.5 mg·ℓ$^{-1}$ of the South African Drinking Water Standard.

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Excellent technologies for defluoridation are available based on using activated alumina or reverse osmosis, but these technologies are not always applicable in rural areas due to financial and technological constraints. Taking into consideration that the estimated capital cost for defluoridation amounts to ca. R5 000 for a 50 ℓ per day unit, based on either of these processes (Schoeman and Steyn, 2000), affordable alternatives, which would be easy to operate and which could be the basis for a house-based or do-it-yourself system, will have to be found. Various methods have been proposed ranging from adsorption on the inner walls of clay pots (Moges et al., 1996) in certain African countries to columns filled with clay brick chips in Sri Lanka (Padmasiri, 1991). Fluoride adsorption onto soils and clays have been studied extensively (Srimurali et al., 1998; Wang and Reardon, 2001) in practically all countries where the problem occurs. In general it was found that the adsorption capacity of soils and the clays was low and kinetics slow. Nevertheless, clay-based systems for defluoridation are used or are under investigation in many parts of the world.

South African clays and soils have not yet been assessed for their potential use as sorbents in house-based defluoridation systems. The purpose of this study was to investigate the adsorption characteristics of South African clay types and to assess their potential as adsorbents for simple defluoridation systems. In addition, the possible enhancement of adsorption capacity by simple physical and chemical pretreatment or activation procedures was investigated.

Clays as sorbents for fluoride

The term clay is often used in a non-specific way and could refer to: (a) soil consisting of a range of small particle sizes (eg. particle size < 1/256 mm on the Udden-Wentworth scale), (b) very fine-grained earthy substances comprising a combination of minerals, inorganic amorphous material and organic matter or (c) a specific clay mineral. The c*lay minerals* are minerals in the phylosilicate mineral group and as the name implies (Greek: *pyllon*, leaf), most of these minerals have a platy habit.

In this study the term clay refers to naturally occurring, very