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Defluoridation of wastewaters using waste carbon slurry

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ABSTRACT

Adsorption of fluoride on waste carbon slurry was investigated. Waste carbon slurry was obtained from fuel oil based generators of a fertilizer industry. The work involves batch experiments to investigate the effects of contact time, pH, temperature and adsorbent dose on the extent of adsorption by carbon slurry. The contact time and pH for maximum fluoride uptake were found 1 h and 7.58, respectively. Maximum adsorption capacity ($4.861\,mg\,g^{-1}$) of fluoride on carbon slurry was observed at $15.00\,mg\,L^{-1}$ initial fluoride concentration using $1.0\,g\,L^{-1}$ adsorbent dose. Among four applied models, the experimental isotherm data were found to follow Langmuir equation more closely. Thermodynamically, adsorption was found endothermic with values $7.348\,kJ\,mol^{-1}$, $-25.410\,kJ\,mol^{-1}$ and $0.109\,kJ\,mol^{-1}\,K^{-1}$ for enthalpy, free energy and entropy, respectively showing the feasibility of adsorption process. From kinetic analysis, the adsorption was found to follow second-order mechanism with rate constant $49.637\,g\,mg^{-1}\,min^{-1}$. The rate-controlling step of the adsorption was found pore diffusion controlled. In order to investigate the potential of this adsorbent on industrial scale, column and desorption experiments were carried out. The breakthrough capacity of column was calculated $4.155\,mg\,g^{-1}$ with at a flow rate of $1.5\,mL\,min^{-1}$. The proposed adsorbent has been used to remove fluoride from groundwater and wastewater. Desorption has been achieved under alkaline conditions (pH 11.6) from exhausted carbon slurry. The performance of carbon slurry was compared with many other reported adsorbent for fluoride removal and it was observed that proposed adsorbent is effective in terms of performance and cost especially.

1. Introduction

Fluoride in nature exists as mineral deposits and, naturally, contaminates our ground water resources. Besides, surface water is also being polluted by fluoride due to various anthropogenic activities. The super-phosphate industry has been a key player in fluoride pollution and exposure of people to fluoride for over a century because phosphate rocks containing fluoride (~5%) are being used in these industries (Arora and Chattopadhya, 1974). In addition, many other industries release fluoride compounds into water, some of which ends up in our food. These include: aluminum smelters, zinc smelters, brickworks, ceramic works, steel mills, uranium enrichment facilities, coal fired power plants, and oil refineries (Paulson, 1977).

Fluoride is very toxic, when it is taken in excess ($3.18\,mg\,L^{-1}$), leading to inhibition of infant's brain/mind development (Lu et al., 2000). This results abnormal behaviors and reduce IQ in children. Dental fluorisis, the first visible sign of fluoride poisoning, affects 8–51% children with drinking fluoridated water, which has substantially increased over the last 40 years (Rix and Donohue, 2005). Fluoridation may cause cancer, osteosclerosis (brittle bones, calcified ligaments) and is also an indicative

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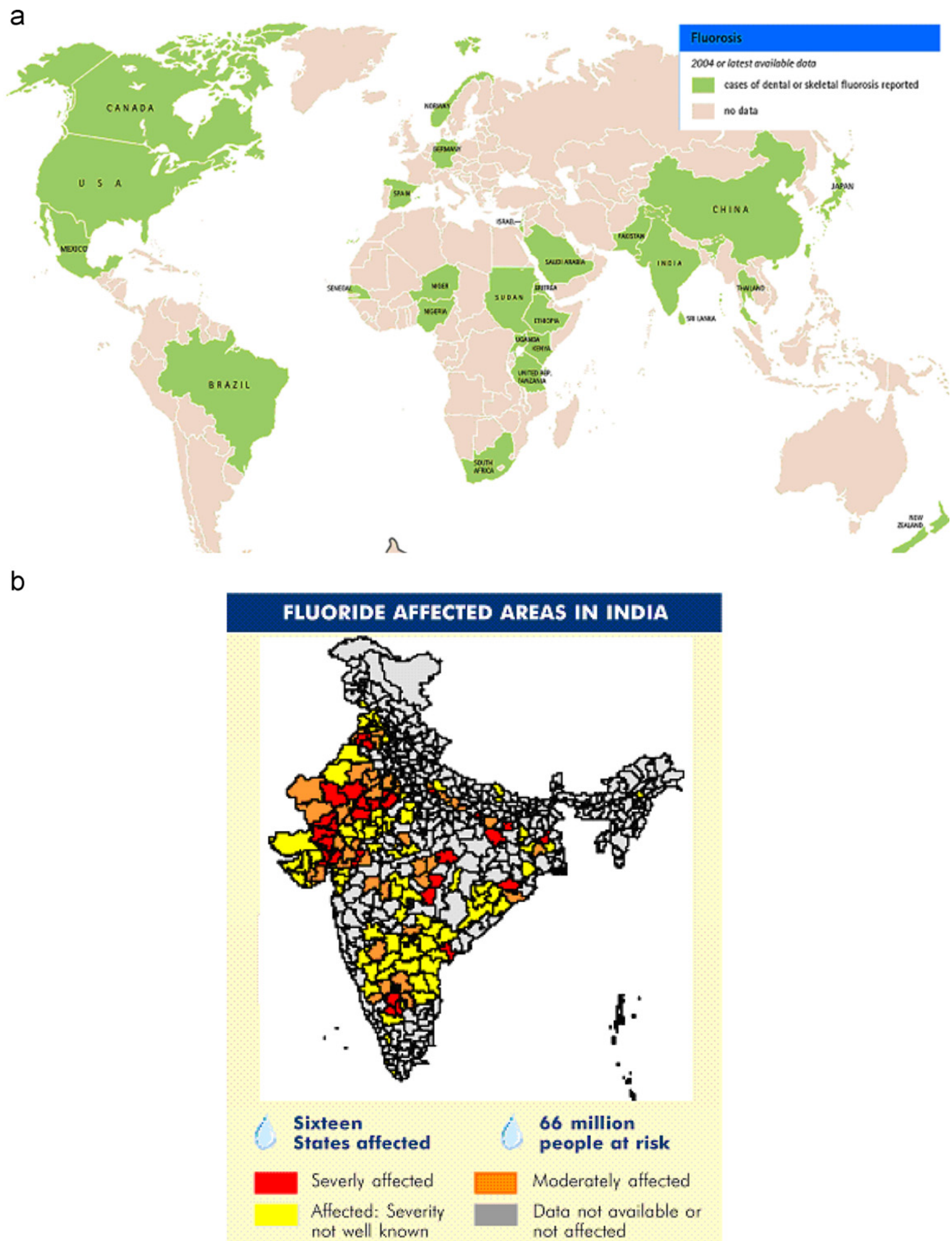

Fig. 1 – Fluoride affected areas: (a) in world and (b) indian scenario of fluoride pollution.

of neurological impairment in human beings (Harrison, 2005).

The permissible limit of fluoride concentration in drinking water is 1.0 mg L^{-1} as per WHO (WHO Technical Report Series, 1994). Fluoride contamination in groundwater is a worldwide problem and many regions have fluoride concentration higher than prescribed by WHO (Fig. 1a), which is a serious threat to flora and fauna including humans (Camargo, 2003). India is also suffering from fluoride epidemic seriously having high concentration of fluoride in 16 states (including 69 districts) with 66 million peoples at risk namely (Fig. 1b; Ravindra and Garg, 2006). The affected states are Andhra Pradesh, Bihar, Gujarat, Haryana, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, West Bengal, Himachal Pradesh and five blocks of Delhi.