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Fluoride ions vs removal technologies: A study

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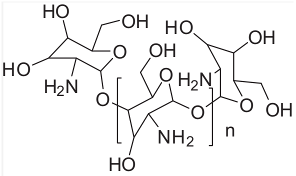
Abstract Literature reported that drinking water is a precious and scarce resource and it has to be protected and kept free from any kind of contamination. Further, it has to be used carefully without wasting. Literature also reported that fluoride bearing rocks are abundant in India, as a result, fluoride leaches out and contaminates the adjacent water and soil resources. A high concentration of fluoride ions in ground water increases up to more than 30 mg/L. This high concentration of fluoride ions causes many harmful and dangerous effects on our datum. Fluoride ions in larger quantities i.e. 20–80 mg/day taken over a period of 10–20 years result in crippling and skeletal fluorosis, severely damaging the bone. In the present scenario, there is a continuously increasing worldwide concern for the development of fluoride treatment technologies. Possibilities of reducing the high fluorine content in groundwater are by defluorination process/dilution with the surface water which is a very simple technique but the addition of Ca^{2+} ions to a solution in contact with fluorite when experimented in distilled water caused an appreciable decrease in fluoride concentration. In this review article, we emphasized the relationship between high concentrations of fluoride ions and their compounds and their health impact.



1. Introduction

Literature reported that fluoride ions are present in low to high concentrations in water. It is a vital substance for humans in preventing cavity and in facilitating the mineralization of arduous tissues if taken in different concentrations. Higher levels of fluoride ions in groundwater may be a world-wide downside

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that varied from country-to-country and continent-continent-to-continent (Reimann et al., 2003). Excess fluoride ions in drinking water are currently found in all regions of the country (Kloos and Tekle-Haimanot, 1999; Tekle-Haimanot et al., 2006). The limit varies among countries and therefore the age of individuals exposed. World Health Organization (WHO) has set a limit between 0.5 and 1.0 mg/L (WHO, 2006).

Fluoride is a very toxic element and known to cause adverse health effects on humans and animals due to environmental and occupational exposure (Krachler et al., 2001). Fluoride has been classified as a priority pollutant by the United States Environmental Protection Agency and the German Research Council (Cabral et al., 2008). The toxicological and physiological behavior of fluoride is dependent on its oxidation state. Elemental fluoride is more toxic than its salts. Hence, its determination is very important because of its implications in health as well as in pharmaceutical formulations.

In various provinces in developing countries e.g. India, the groundwater is rich in halide and the provisions of different installations are tough. Treatment of contaminated water is the sole choice to offer safe drinking water. India has concerning seventieth rural and quite twenty to half-hour of urban population in several states, depends on spring water for its domestic demand. High concentrations of fluoride ions in water render it unfit for drinking. Fluoride ions are a vital part of drinking water however at a higher concentration i.e. around 1.5 mg/L might cause harmful effects on human health. Its contamination in water has been recognized as a worldwide downside and its concentration in drinking water at several places of the planet exceeds the permissible limits (Swain et al., 2012). Interference of halide with carbohydrates, lipids, proteins, vitamins and mineral metabolism is reported to be attributable to the presence of high concentrations of it in water and intake of higher quantities of fluoride has been reported to result in dental and skeletal pathology (Gong et al., 2012). The Bureau of Indian Standard (BIS) suggested a fascinating limit of one milligram per liter of it in drinking water, which may be extended to 1.5 mg/L as permissible limit, if no totally different supply of drinking water is accessible (BIS, 1991/2003). Various technologies like sorption, natural process, precipitation, electro-dialysis and reverse diffusion are used for the removal of halides mostly fluoride ions from water (Sujana et al., 2009; Kagne et al., 2008; Wu et al., 2009; Biswas et al., 2010; Viswanathan and Meenakshi, 2010; Sundar et al., 2008; Quiroz et al., 2011).

Literature reports a wide variety of methods for the trace level determination of fluoride. Various methods available for the determination of fluoride are, high-performance liquid chromatography with hydride generation-atomic fluorescence spectrometry (HPLC-AFS) Ferreira et al., 2009, non-chromatographic hydride generation-atomic fluorescence spectrometry (Torok and Žemberyova, 2010), electro-thermal atomic absorption spectrometry (AAS) Araujo et al., 2010 high-resolution continuum source graphite furnace atomic absorption spectrometry (Krachler and Emons, 2001), high performance liquid chromatography-inductively coupled plasma-mass (ICP) spectrometry Bosch et al., 2010; Adeloju and Young, 1995 etc. However, these methods are time consuming, costly and laborious.

Electro-analytical methods (Adeloju et al., 1998; Santos et al., 2009; Tanguy et al., 2010; Huiliang et al., 1987; Agrahari et al., 2009), on the other hand, offer the advantages of low-cost, ease in sample handling, and above all, extremely high sensitivity and are thus the methods of choice for the detection and trace-level determination of fluoride. Chemically modified electrodes (CMEs) have been employed widely in the trace level determination of both metal ions (Khani et al., 2010; Sanghavi and Srivastava, 2011) as well as organic molecules (Ghalkhani and Shahrokhian, 2010; Shahrokhian and Asadian, 2010). CMEs in the form of carbon paste electrodes (CPEs) have been extensively used due to their wide anodic potential range, low residual current, ease of fabrication, easy surface renewal, and low cost. Plain carbon paste electrode (PCPE) has been modified employing various modifiers, viz., nanomaterials (Gadhari et al., 2010; Sanghavi and Srivastava, 2010), surfactants (de Oliveira et al., 2007), copper complexes (Mobin et al., 2010; Vaze and Srivastava, 2007), macrocycles (Kotkar et al., 2007; Shahrokhian et al., 2009), etc. Glassy carbon electrodes (GCEs) are very versatile as electrode materials for trace level determination of organic molecules as they provide high sensitivity, negligible porosity, and good mechanical rigidity. GCEs have been modified by means of various modifiers viz., chitosan, nanomaterials, etc. (Shahrokhian and Ghalkhani, 2010; Zhang et al., 2010; Vaze and Srivastava, 2007).

CPEs are very popular due to their wide anodic potential range, low residual current, ease of fabrication, easy surface renewal and low cost. CMEs are used to lower the detection limits compared to plain carbon paste electrodes (PCPE). Various modifiers, such as macrocyclic compounds (Gaichore and Srivastava, 2010; Mobin et al., 2010), copper complexes (Inês Rosane de Oliveira et al., 2007; Shahrokhian et al., 2009), phthalocyanine (Rivas et al., 2007) and nanomaterials (Yang et al., 2009) have been employed successfully as modifiers for carbon paste electrodes. Carbon nanotubes (CNTs) have triggered a new genre for the development of novel electrode materials due to their amazing structural, mechanical, electrical and physical properties (Dai et al., 2009; Beitollahi et al., 2008; Zhu et al., 2008; Svancara et al., 2008; Gavalas et al., 2004). In addition, surfactants at trace levels have also been employed successfully as modifiers (Jain et al., 2009; Zhang et al., 2002; Li, 2007; Xu et al., 2009; Yang et al., 2009). Carbon nanotubes (CNTs) have started a new era for the development of novel electrode materials due to their amazing structural, mechanical, electrical and physical properties (Kasprzyk-Hordern et al., 2010; Yang et al., 2010).

They have been successfully used as modifiers to obtain very low detection limits. Nafion, a perfluorinated sulfonated cation exchanger with properties of excellent antifouling capacity, chemical inertness and high permeability to cations, has been extensively employed as an electrode modifier for organic molecules (Chou et al., 2009; Cheng et al., 2008; Gadhari et al., 2010). However, these methods have the drawbacks like high cost and laboriousness (time taking) and require pretreatment of the samples. Modern electro-analytical techniques, on the other hand, are extremely sensitive, selective, and do not need pre-treatment or pre-separation. The availability of various chemically modified electrodes at relatively low cost has provided considerable impetus to the use of electro-analytical techniques for analysis of organic molecules as well as metals (Diawara, 2008).

In several cases, the water sources are rendered unsafe not just for human consumption however additionally for different activities like irrigation and industrial wants. Therefore, now

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