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METHODOLOGIES OF DEFLUORIDATION OF WATER-A REVIEW

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ABSTRACT

Fluoride pollution in environment occurs through natural sources and anthropogenic sources. The discharge of industrial wastewater, such as semiconductor industries, aluminium industries, and glass manufacturing industries, contribute to fluoride in water pollution, especially in groundwater. This paper reviews the methodologies adapted for fluoride removal from water such as Ion exchange, Membrane process, Electrocoagulation, Adsorption, coagulation and precipitation

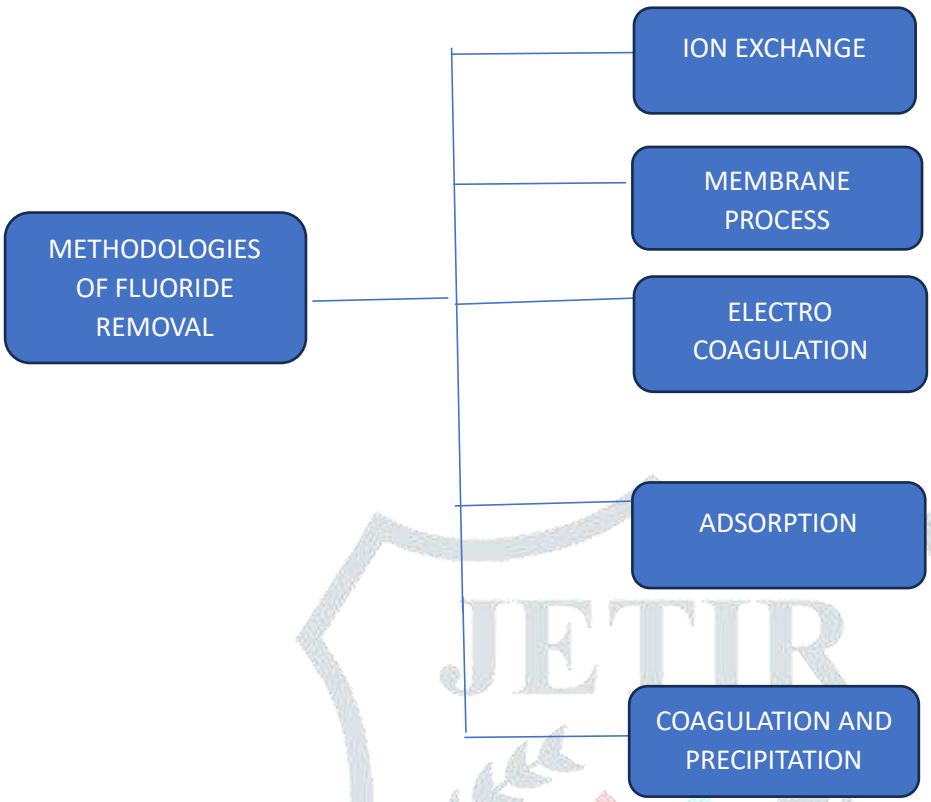
Key words: Fluoride, water, Ion exchange, Membrane process, Electrocoagulation, Adsorption, coagulation and precipitation.

INTRODUCTION

Fluoride exists either as inorganic fluorides or organic fluoride compounds. Fluorine is a chemical element with atomic number 9 and is a halogen element belonging to group 17 of the periodic table. Molecular fluorine (F_2: gaseous state) is an irritant and explosive toxic gas and is very unstable at room temperature, hence, is not found in nature[1]Most of it exists as the highly electronegative fluorine ion (F^-) or as a fluorine compound. Fluorine is a non-metallic element that is chemically very active and reacts with most substances to form compounds, thus playing an important role in industry, medicine, and the environment[2]. Some fluorine compounds include hydrogen fluoride (HF), sodium fluoride (NaF), and calcium fluoride (CaF_2).

Various products like quartz glass, precious metal recovery, and semiconductors need fluorides as necessary chemical in processing. So industrial effluents of the above industries contain fluorides or hydrofluoric acid as main pollutants.[3]. Ingestion of more than 5 mg/L of fluoride can cause toxicity to humans leading to great health hazards such as dental fluorosis, osteoporosis, arthritis, and brain damage [4-5]. According to WHO, the maximum acceptable concentration of fluoride is 1.5 mg/l [6]. While India's permissible limit of fluoride in drinking water is 1mg/l[7]. The methodologies for removal of fluoride from water includes Ion

exchange process, Membrane process, Electrocoagulation, Adsorption, Coagulation and Precipitation. In this review various approaches for defluouridation of water from this field of research has been assessed.



TECHNIQUES FOR DEFLUORIDATION OF WATER

ION-EXCHANGE PROCESS

Fluoride can be removed from water supplies with a strongly fundamental anion-exchange resin containing quaternary ammonium functional groups. The fluoride ions substitute the chloride ions of the resin.This process proceeds until every one of the sites on the resin are possessed. The resin is then backwashed with water that is supersaturated with dissolved sodium chloride salt. New chloride ions then substitute the fluoride ions prompting recharge of the resin and beginning the process once more. The driving force for the substitution of chloride ions from the resin is the stronger electronegativity of the fluoride ions[8] Chikuma and Nishimura studied the fluoride removal by a chloride loaded anion exchanger, Amberlite IRA-400. The chloride ions held on the surface of this resin were exchanged for fluoride ions in aqueous solution [9].

MEMBRANE PROCESS

Membrane processes like nanofiltration(NF) and reverse osmosis (RO) effectively remove fluoride from wastewater. RO and NF uses semi-permeable membranes that selectively allow water molecules to pass through while retaining fluoride and other contaminants.

Tahaikt et al. studied fluoride removal from water with three commercial membranes with different configurations. The obtained fluoride rejection varied with initial fluoride content but exceeded 74% for

NF270 and TR60. For NF90, which is less sensitive to initial fluoride concentration, fluoride rejection exceeded 98%[10]. Ezzeddine et al investigated a hybrid process that combined the precipitation with hydrate lime along with reverse osmosis (RO) treatment to deal with effluent discharged from an aluminium fluoride manufacturing unit which had an excessive fluoride concentration of 3,200 mg/L. Neutralization with hydrated lime using excesses above 50% at pH 7–8 led to fluoride removal rates higher than 98%. The industrial effluent neutralized under optimal conditions underwent an RO treatment that allowed to reduce the fluoride content to about 8 mg/L giving an overall removal of 99.9% F^-.[11]

ELECTROCOAGULATION

Electrocoagulation (EC) method is a method in which an electricnfield is applied to the electrolyte to generate metal ions, which coagulate impurities and bind the material to form a precipitate [12]. The advantages of electrocoagulation include highly efficient particulate removal, compact treatment facility and the possibility of complete automation of the process[13] Suitable electrode choice is very important in electrocoagulation. Most common electrode materials are iron and aluminium. Both of these are cheap, easily found and effective materials [14]. Electrocoagulation is a combination of oxidation, flocculation and flotation. Electrocoagulation occurs in three steps: in the first step, coagulant is formed because of oxidation of anode; in the second step, pollutants are destabilized; and in the last step, destabilized matters are united [15]. Drouiche et al investigated fluoride removal by Electrocoagulation using bipolar iron electrodes of photovoltaic wastewater containing fluoride. Synthetic solution of 1000 ml containing 25 mg/l F–, having initial pH 6.4 after electrocoagulation at 58.82 A/m^2 current density for 30 min brings down the discharge standards to 15 mg/l.[16]

ADSORPTION

The adherence of molecules or particles to the surface of a solid or liquid is known as adsorption. Adsorption offers high removal efficiency for fluoride ions from wastewater. The various factors that affect adsorption process are pH, temperature, pollutant concentration, adsorbent dosage, etc., which are optimized to obtain the best result [17]. Naincy Sahu et al explored the applicability of waste pea peel as adsorbent for the elimination of fluoride ions from aqueous medium. The pea peel was modified with iron ($FeCl_3$) for enhancing its adsorption efficiency. In batch study, the maximum fluoride removal 99% was found at 5 mgL^{-1} initial fluoride concentration at neutral pH, 4 gm/L dose, and 420 min contact time. The maximum removal capacity at column system was found 3.75 mg/g[18]. Thouraya Turki et al evaluated fluoride ion adsorption on modified zeolite clinoptilolite to increase its affinity for fluoride ions. The maximum removal efficiency was 94% at 5 mg/L fluoride initial concentration, pH 6.3, and 0.5 g modified zeolite mass. [19]

COAGULATION AND PRECIPITATION

In precipitation process, chemicals are added which leads to fluoride precipitate formation and the process produces certain amounts of sludge. On the other hand, in coagulation method, wastewater is treated with calcium hydroxide for controlling pH, and formed calcium fluoride precipitate can be removed by solid separation process[20]. coagulation process has received a lot of attention for the removal of pollutants such as fluoride from water due to the features such as low energy consumption, relatively simple design and easy operation [21]. Hu et al. reported that at the molar ratio of hydroxide and fluoride ions to Al (III) ions close to 3 the efficiency of system for fluoride removal was 100%[22]. Gong et al. investigated the effects of aluminum fluoride complexation on the removal of fluoride by Al salts coagulation. Results showed that the optimal pH for total fluoride removal was 7 and the aluminum fluoride complexes are favored at low pH and high fluoride concentration but this condition had negative effect on the fluoride removal [23]

CONCLUSION

This review has analysed the methods of removal of fluoride from water. Effective removal of fluoride from water can be done by these methodologies. The choice of treatment method need to be based on evaluation of site-specific conditions, ensuring maximum defluoridation and economical fluoride elimination in water treatment applications

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