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Defluoridation Using Adsorption- Zirconium Impregnated Activated Bagasse Carbon

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Abstract:
One of the major contaminants in drinking water is the excessive presence of fluorine (F), one of the most abundant anions present in groundwater. Excessive intake of fluorine ion through drinking water causes serious health hazards like dental and skeletal fluorosis affecting humans and environmental problems like low yield and plant growth. Fluoride contaminated groundwater poses a significant public health concern to rural population with unaffordable purification technology. The acceptable limit of Fluorine is 1mg/L and therefore the permissible limit is 1.5mg/L. If the concentration of fluoride exceeds 1.5mg/L, dental fluorosis occurs and if concentration exceeds 4mg/L skeletal fluorosis is likely.
There are several technologies are used for the defluoridation from potable water, of which adsorption processes are generally used more due to their effectiveness, convenience, simple operation, simplicity of design, and for economic and environmental reasons. In this project our aim is to conduct a study on the fluorine removal efficiency by adsorption technology using Zirconyl Chloride impregnated activated bagasse carbon as adsorbent.

***Key Word**: Fluoride, Defluoridation, Dental and skeletalfluorosis, Adsorption, Environmental, technology.*

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I. Introduction

Water is one among the foremost important elements for all sorts of life and is indispensable to the upkeep of life on earth. Safe drinkable water is the primary need of each person. Within the recent past, there has been excessive dependence on groundwater to satisfy potable water needs. Groundwater contamination occurs when pollutants are released to the ground and make their way down into groundwater. Pollution may also occur naturally because of the presence of a minor and unwanted constituent, contaminant or impurity within the groundwater. One such contaminant is fluoride. If groundwater passes through fluoride-rich rocks, it dissolves the fluoride and therefore the water consequently can have more than the suitable level of fluoride. In 2011 the World Health Organization suggested a level of fluoride from 0.5 to 1.5mg/L, reckoning on climate, local environment, and other sources of fluoride. Many people around the globe are still deeply dependent on groundwater encompassing an elevated level of fluoride. The newest estimates suggest that around 200 million people, from among 25 nations are deeply dependent on groundwater with elevated levels of fluoride. India and China, the 2 most populous countries of the planet, are the worst affected. (Rasool A et al., 2018) The government of India says that as of April 2014, fluoride prevalence was reported in 230 districts in 19 Indian states, with over 14,000 homes within the risk areas still lacking safe potable water. The population in danger is officially estimated to be around 11.7 million, although NGOs warn that the threat is far more widespread, affecting over 60 million people nationwide affected by dental, skeletal, and non-skeletal fluorosis. Out of those, almost six million are children below the age of 14 years. Supported the survey conducted with the assistance of state agencies, 8782 children in Kerala, 4 lakhs in Karnataka, 15,643 in Tamil Nadu, and 9,777 in Telangana are affected with fluorosis. In Kerala, high fluoride content and numerous cases of fluorosis are reported within the districts of Palakkad and Alappuzha.

Fig.1.a:Mild dental fluorosis

Fig.1.b:Skeletal fluorosis

Ingestion of excess fluoride, most commonly in drinking-water, causes adverse effects of health such as skin lesions, arthritis, Alzheimer's disease, thyroid disorders, cardiovascular disorders, dental fluorosis, and skeletal fluorosis. Moderate amounts of fluorine (>1.5mg/L) lead to dental effects, but long-term ingestion of large amounts (>4mg/L) can lead to potentially severe skeletal problems. In plants, excess Fluoride content can inhibit germination, cause ultra-structural malformations, reduce photosynthetic capacities, alter membrane permeability, etc. Because fluorosis is an irreversible condition and has no cure, prevention is the only solution. (WHO,2001)

Objectives

The objective of the project is to identify cheap and sustainable defluoridation technology using chemicals and natural materials. The technology we adopted was adsorption using activated carbon manufactured from sugarcane bagasse. To increase the efficiency of adsorption, a study was conducted on adsorption impregnated with zirconium metal ions. The main objective of the project is to determine the efficiency of fluoride removal by adsorption using Zirconyl Chloride ($[Zr_4(OH)_8(H_2O)_{16}]Cl_8(H_2O)_{12}$) impregnated sugarcane bagasse as adsorbent.

Scope

- Identification of the effects of excess fluoride in drinking water sources.
- Selecting cheap and sustainable sugarcane bagasse as raw material for defluoridation using adsorption
- Activation of adsorbent material (sugarcane bagasse) using concentrated Sulphuric Acid (H_2SO_4) and sodium bicarbonate
- Improving the adsorption capacity by impregnating the activated carbon with non-toxic Zirconyl Chloride
- Calculating the efficiency of fluoride removal.

II. Material and methods

Selection of Adsorbent

Most commonly used adsorbents are activated carbon and activated alumina. In the study, dried sugarcane fiber waste was the material used for production of the activated carbon. As sugarcane bagasse is easily available and cheap, the chemical synthesis of activated carbon was not a difficult process, so it can be used as an effective adsorbent for removal of fluoride ions from solution.

Preparation of Activated carbon (AC)

Collected sugarcane bagasse washed with distilled water to remove impurities and dried in sunlight over a period of time. Then it is treated with one portion of concentrated Sulphuric acid (H_2SO_4) and heated in air oven for 24 hours at 150˚C. After washed with distilled water, it is soaked in 1% Sodium bicarbonate solution overnight to remove residual acid.The material was dried in an oven at 105˚C for 24 hours. The activated carbon was placed in an airtight container for further use.

Fig 2: Activated Bagasse Carbon

Preparation of stock solution
Dissolving 221 mg of anhydrous sodium fluoride (NaF) in 1000ml distilled water to get 100mg/L fluoride.

Preparation of SPADNS Reagent
192 mg of SPADNS is measured and dissolved in 100 mL deionized water. 26.6mg of Zirconyl chloride was added to 25ml distilled water along with 20ml of HCl and the solution was made up to 100ml using deionized water. To produce an indicator complex, equal volumes of SPADNS and Zirconyl chloride solution were mixed. It should be stored in airtight container and kept in dark.

Fluoride standard samples of concentration ranging from 0.5mg/L to 10mg/L were then prepared from the stock solution. Corresponding absorbance was determined using the SPADNS reagent in spectrophotometer. From the calibration graph which is plotted between concentration Vs absorbance values obtained, it was found that as the concentration of the fluoride increases the absorbance decreases**.**

Preparation of Zirconyl Chloride Impregnated Activated Bagasse Carbon
To Preparation of Zirconyl chloride impregnated activated carbon, activated bagasse carbon was soaked in 5% Zirconyl chloride solution for 3 days. It was then oven dried at 106°C for 24hours.

Test Procedure
Fluoride concentration was determined by model-104,Systonics spectrophotometer which has an accuracy of ± 5nm and wavelength range of 340-960nm (normal range for fluoride-570nm) using SPADNS reagent. Each material was tested individually where the stock solution of various concentrations was passed through the test setup, to find out the efficiency and optimum dosage.

Batch study using adsorption Zirconyl chloride impregnated Activated Bagasse carbon
To conduct the adsorption test, a 2L sample with 5mg/L concentration was mixed with ZirconylChloride impregnated activated carbon using the stirrer at 100rpm. The sample in the jar was kept for 120 minutes with 15 minutes interval, and then the defluoridated water was collected from the jar. Then it was filtered using Whatman 42 filter paper. Then the absorbance of defluoridated water was determined using SPADNS reagent, and the efficiency was calculated using initial and final concentration. The test was conducted to determine optimum dosage of the adsorbent and its optimum time for defluoridation treatment.

III. Result

Effect of dosage

Various doses of Zirconyl chloride impregnated activated carbon used for defluoridation were 4g/L to 14g/L at an interval of 2g/L. The results are shown in 'removal efficiency Vs dosage' graph. It can be seen that efficiency increases as the dosage increases. The trend continues till14g/L dose after which the adsorption remains constant. Hence the optimum dosage obtained is 14g/L. Fig.3 illustrates removal efficiencies of different dosages at optimum time of 105 minutes.

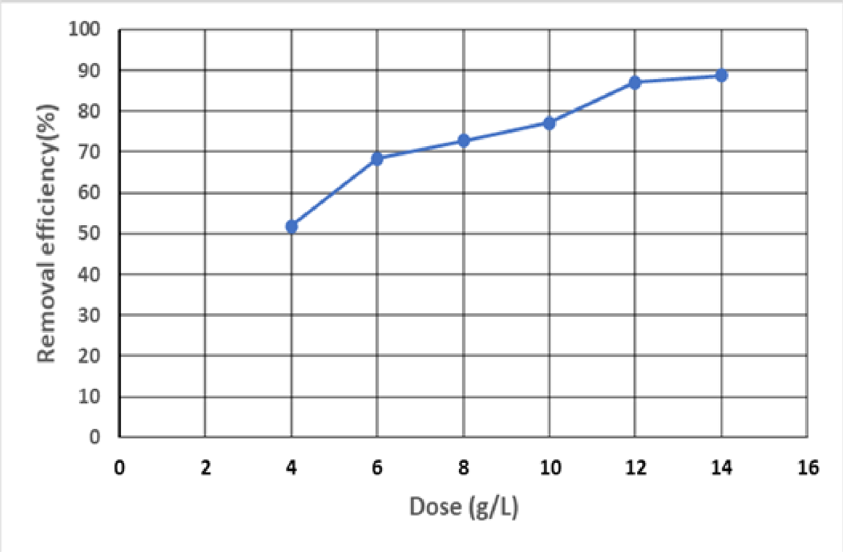

Fig 3 : Dose Vs removal efficiency

Effect of contact time

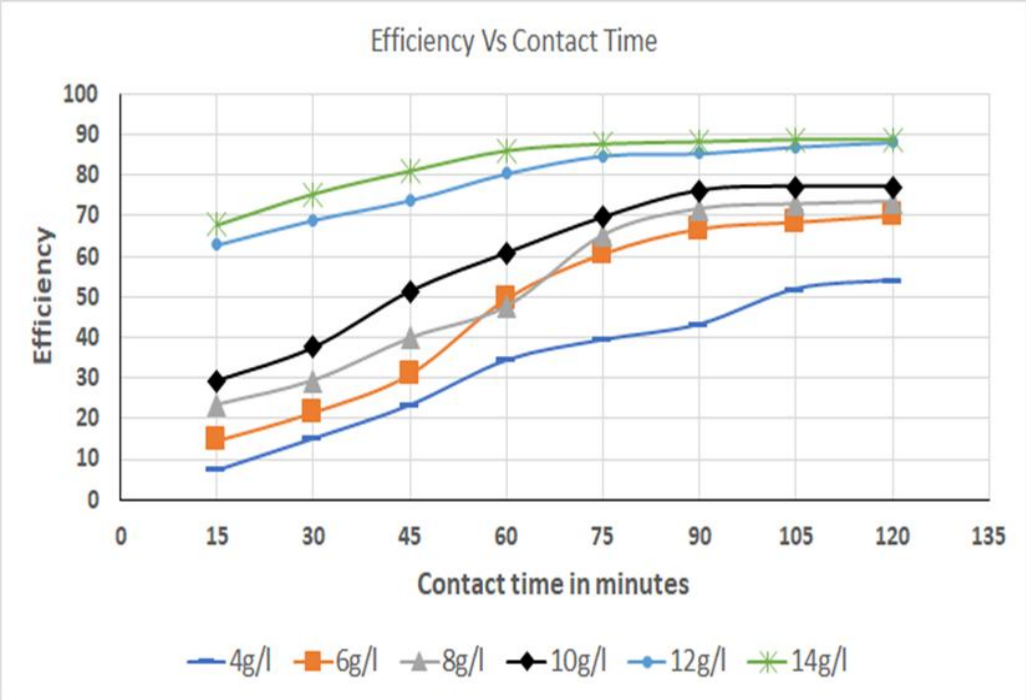

Fig 4 : contact time Vs efficiency

The effect of contact time at dosages 4, 6, 8, 10, 12 and 14g/L of Zirconyl chloride impregnated with activated carbon were studied. **Fig.4** illustrates a graph between removal efficiency and contact time for different dosages. In most of the cases, removal efficiency constant at 90,105 and 120 minutes.

IV. Conclusions

Contamination of groundwater could be a growing problem in several parts of the globe . In India approximately ground levels. Kerala 60 million people are exposed to groundwater with elevated, as a state, has gentle problems with fluoride contamination. However regionally it will be a large problem.

Different adsorbent materials were studied for testing the efficiency for fluoride removal in various tests and seem to offer a very cheap useful product for effective defluoridation.

In the present study, the characteristics of Zirconyl Chloride impregnated with sugarcane bagasse as activated carbon was studied for the removal of fluorine in laboratory studies and we found that it will be a promising solution for defluoridation.

For the study, different dosages 4,6,8,10,12 and 14g/L of Zirconium impregnated activated sugarcane bagasse were taken. It was found that as the dosages increased fluorine removal efficiencies also increased and optimum dosage was found as 14g/L.

Maximum efficiency was obtained at 105 minutes, after conducting experiments for each dosages at 15, 30, 45, 60, 75, 90, 105 and 120 minutes at an interval of minutes. The efficiency obtained for 12g/L at 120 minutes was 88.14%. For 14g/L the corresponding efficiency was obtained at 90 minutes which is 30 minutes earlier, though there is a negligible increase in removal efficiency as time increases. Due to inexpensive sugarcane fiber waste and fewer expensive chemicals, there is no chance of high material cost. So, the excess addition of dosages results in higher efficiency in a short time, thus operation cost can be minimised.

The removal efficiency was found to increase morethan 70% from a stock solution of 5ppm fluoride with optimum dosage of 14g/L of Zirconyl Chloride impregnated with sugarcane bagasse as activated carbon at a contact time of 105 minutes. Fluoride removal efficiency of this technique is comparatively high. Thus, it can be concluded that this adsorption method is most effective, cost efficient and reliable for defluoridation from groundwater.

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