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Experimental Study of Fluoride Removal from Drinking Water through the Use of Sand as Adsorbent by Solar Distillation

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Abstract - Fluoride is often described as a 'double-edged sword' as inadequate ingestion is associated with dental caries, where as excessive intake leads to dental, skeletal and soft tissue fluorosis- which has no cure. Considering the fact that fluorosis is an irreversible condition and has no cure, prevention is the only solution for this menace. Fluorides in drinking water may be beneficial or harmful depending on their concentration and total amount ingested. Fluoride is advantageous mainly to young children for calcification of dental enamel when present within permissible limits, but when it presents in excess amount in drinking water for long duration, various ailments that are collectively referred to as fluorosis occur.[1] Indian standards for drinking water recommend an acceptable fluoride concentration of 1.0 mg/L and an allowable fluoride concentration of 1.5mg/L in potable waters.[2] There are many techniques are available for fluoride removal viz. Electrocoagulation, ion exchange, adsorption etc.[3] In the present work, an inclined basin-type solar still containing sand and water has been used at Kanpur for fluoride removal. It has used both the method of solar distillation & adsorption for fluoride removal. The still effectively removes F^-. For water samples having a fluoride concentration in the range 2–10 mg/L, the fluoride concentration in the distillate was usually <1.5 mg/L. Precipitation on the upper surface of the still was collected, and its fluoride concentration was established to be below the required limit of 1.5 mg/L. Hence it can also be used for cooking and drinking.

***Key Words**:* De-fluoridation; Adsorption; Solar still; Solar Distillation

1. INTRODUCTION

Water is a vital natural resource for sustaining life. Water is certainly not free everywhere. However, chemical composition of surface or subsurface is one of the prime factors on which the suitability of water for domestic, industrial, or agrarian purpose depends. Though groundwater contributes only 0.6% of the total water resources on earth, it is the main and chosen source of drinking water in rural as well as urban areas, particularly in developing countries like India. It accommodates 80% of the total drinking water necessity and 50% of the agricultural requirement in rural India. In the current era of economic growth, groundwater is getting polluted due to anthropogenic activities like urbanization, industrialization & agriculture etc. in addition to geogenic contamination. Fluoride is one of the most abundant anions present in groundwater worldwide that has been shown to cause significant effects in people through drinking-water. Fluoride has beneficial effects on teeth at low concentrations in drinking-water, but excessive exposure to fluoride in drinking-water, or in combination with exposure to fluoride from other sources, can give rise to a number of adverse effects. These range from mild dental fluorosis to crippling skeletal fluorosis as the level and period of exposure increases. Crippling skeletal fluorosis is a significant cause of morbidity in a number of regions of the world.

In India, the first case of Fluoride detection in drinking water was happen at Nellore district of Andhra Pradesh in 1937. Since then, a large number of papers have been published on de-fluoridation or the removal of fluoride, but the problem of fluorosis persists. Presently, 17 states of India, especially Rajasthan, Madhya Pradesh, Andhra Pradesh, Tamil Nadu, Gujarat, and Uttar Pradesh have being facing the problem of fluorosis at a large extent.[4] At present, in India, endemic fluorosis is thought to affect ~1 million people.[5]

The current work deals with experiments on the use of solar distillation for fluoride removal through the use of adsorbent base of sand. In past, it was mainly used for desalination of seawater and brackish water,[6–12] but studies on its use for de-fluoridation have been reported only recently.[13–16] This paper is mostly inspired from the work of Anjaneyulu.et. Al,[16] in which data related to volume of distilled water & its fluoride content was collected for 2 years. Results of research work of Anjaneyulu.et. Al shows that modified solar still with sand as an adsorbent is an effective technique for de-fluoridation, if the feed concentration $c_f \leq 5$ mg/L. In the present work, data were collected for a period of 7 days, using still with different raw water sample having varying concentration of fluoride in it ranging between 2-15 mg/l. Further, the variation of the volume of the distillate with the day of operation has been also reported.

2. Experimental details-

2.1. Materials-

Mainly following material are used in de- fluoridation of raw water-

2.1.1. Sand

2.1.2. Synthetic fluoride water was prepared by dissolving different quantity of anhydrous sodium fluoride in distilled water.

2.1.3. Thermocol as an insulating material

2.2. Experimental Setup & Methodology-

A water basin of GI sheet of size 1 m^2 was placed inside a wooden frame of larger size & covered by a glass sheet of 3.5 mm from upside at a tilt of 26.5°. The solar still was insulated by using thermocol as an insulating material. The still had an inlet for feeding the water and a channel for collecting the distillate. At the lower end of the still, a plastic pipe of semicircular cross section was attached to collect the rainwater incident on the upper surface of the glass plate .(fig. 2,3 & 4)

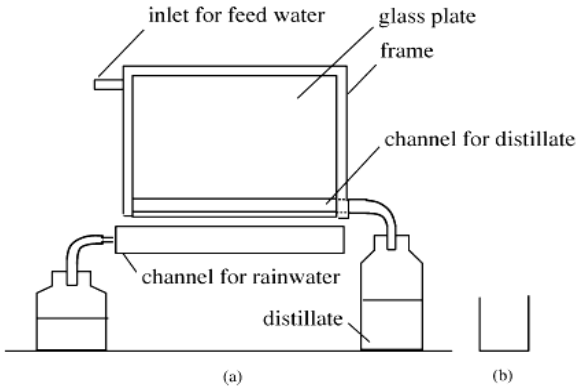

Figure1. (a)Elevation of the still; (b) cross section of the distillate channel.

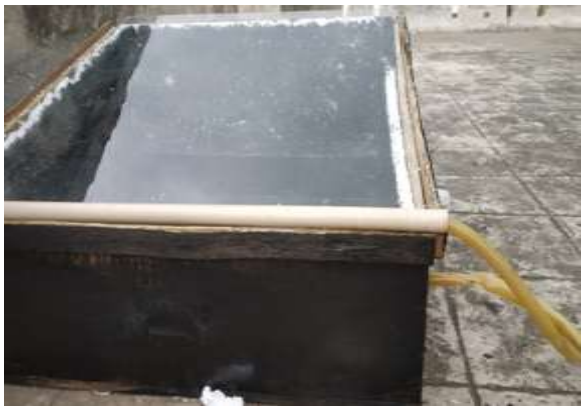

Figure2. Modified Solar Still

The stills were placed on the terrace of DBRA 2 hostel of HBTU at Kanpur (26.50° N, 80.27° E). Experiments were conducted from May 12, 2019 to May 18, 2019. The concentration of fluoride in feed water C_{ff} & concentration of fluoride in distilled sample C_{fd} measured daily using a spectrophotometric method.[17] The daily productivity of distilled output from solar still was also measured. Other chemical & physical quality of distilled water was also determined through the different laboratory test.

To determine the impact of pH & temperature of feed water on the concentration of fluoride of distilled output, some other arrangements were done. The pH of feed water was varied by adding 8N NaOH solution in different quantities & the temperature of feed was varied by heating it over stove to a desired temperature before pouring it into the still.

The efficiency of fluoride removal in the present process can be express as-

$$\%R = \frac{C_{ff} - C_{fd}}{C_{fs}} * 100$$

3. Results and discussion-

3.1. Volume of distilled output –

The volume of extracted water mainly varied from 2.9 to 3.4 L/m^2/day during 7day period. The variation in the distilled output was mainly depending on the solar irradiance & other climatic factor. The concentrations of F- in feed have no impact on the volume of distilled.

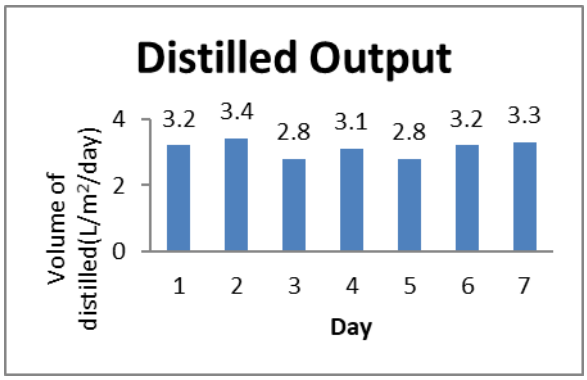

Figure3. Cumulative **v**olume of distilled water (L/m^2/day)

3.2. Fluoride concentration of distilled water-

When the simple tap water having fluoride concentration of 0.52 mg/L had supplied into solar still, the fluoride concentration in purified water was shown 0 as it was below the detection limit of 0.3 mg/L. The concentration of fluoride of distilled C_{fd} was found below 0.6 mg/L for the $C_{ff} \leq 7$ mg/L. For the 7 mg/L< $C_{ff} \leq 15$ mg/L, the value of C_{fd} was found between 0.5 to 1.4 mg/L which is almost below the permissible limit of 1 mg/L.

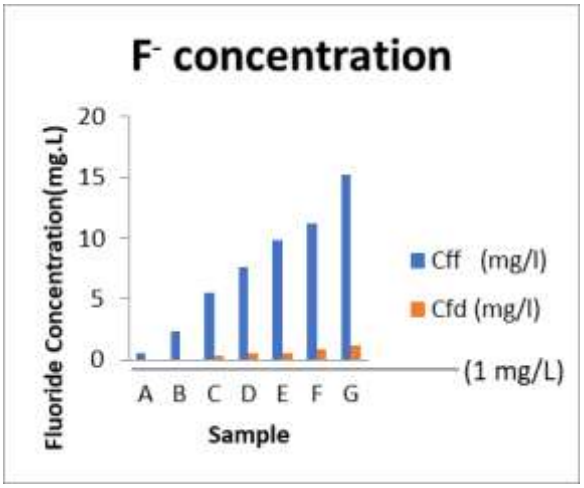

Figure4. Fluoride concentration of feed & distilled

3.3. Fluoride removal efficiency of solar still-

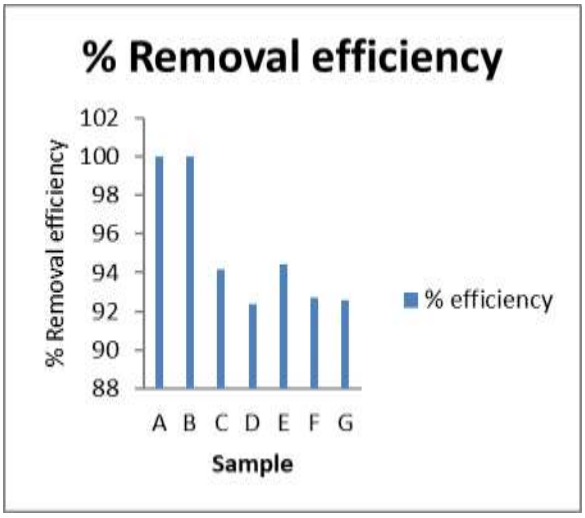

Figure5. Fluoride removal efficiency of solar still

Solar still effectively remove the fluoride contamination through the process of solar distillation & adsorption. It's % removal efficiency was almost above 90% .

3.4. Effect of temperature of the Feed on the Concentration of F− in the Distillate-

We had varied the temperature of the feed after keeping the fluoride concentration of feed constant at 10 ± 0.8. The values of C_{fd} were mostly independent of temperature of feed. The data show almost similar value of C_{fd} at different temperature of feed.

4. Conclusion-

Solar distillation system efficiently removed the fluoride content from feed water with more than 90% efficiency. For the $C_{ff} \leq 5$ mg/L, It removed fluoride completely from water. For C_{ff} in the range 10−15 mg/L, most of the fluoride is removed, but its concentration in the distillate, cd, may exceed slightly the desirable limit of 1 mg/ L in some cases. The results of this work were almost comparative to the study of Anjaneyulu.et. Al. The values of cd were found to be approximately independent of the pH of the feed and the feed temperature, for pH values in the range 6.5−10.0 and feed temperatures in the range 24−60 °C. At last, solar distillation provide a ray of hope to the people in remote areas & areas having arid atmosphere, who have been battling the scourge of fluorosis for many decades.

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BIOGRAPHIES

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