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Low Cost Household Level Solution To Remove Fluoride From Drinking Water

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Abstract: Water with high fluoride content is unsafe not only for human consumption but also for other activities such as irrigation and industrial needs. Therefore, a systematic assessment of fluoride in groundwater is required for the better management of the fluoride toxicity. Defluoridation of drinking water is the only practicable option to overcome the problem of excessive fluoride in drinking water. Therefore in this paper it was aimed to find a suitable low cost environmental friendly method for removal of fluoride in the drinking water that could be used by common man, easy to understand and can be adopted in rural as well as urban background throughout the year. Other possible negative impacts i.e. handling of dangerous chemicals, consequences of wrong dosing of chemicals and possible chemical residuals were also avoided.
Keywords: High fluoride; Deflouridation; Low cost environmental friendly method.

Introduction:

Water is an essential resource for living systems, industrial processes, agriculture production and domestic use. Over the past few decades, the ever-growing population, urbanization, industrialization and unskilled utilization of water resources have led to degradation of water quality[1–2]. Presence of various hazardous contaminants like fluoride, arsenic, nitrate, sulfate, pesticides, other heavy metals etc. in underground water has been reported[3-5]. It is estimated that around 260 million people worldwide (in 30 countries) are drinking water with Fluoride content more than 1.0 mg/L (The drinking water standard for fluoride set by WHO)[6]. Fluoride in minute quantity is an essential component for normal mineralization of bones and formation of dental enamel[7]. However, its excessive intake may result in slow, progressive crippling scourge known as fluorosis (as shown in table 1). In India alone, endemic fluorosis is thought to affect around one million people and is a major problem in 17 of the 25 states, especially Rajasthan, Andhra Pradesh, Tamil Nadu, Gujarat and Uttar Pradesh. It has also been observed that low calcium and high bicarbonate alkalinity favor high fluoride content in groundwater[8-9]. Water with high fluoride content is generally soft, has high pH and contains large amount of silica. That is why in many cases, the water sources have been rendered unsafe not only for human consumption but also for other activities such as irrigation and industrial needs.

Table 1 : Effects of fluoride in water on human health

Fluoride concentration (mg/L)	Effects
<1.0	Safe limit
1.0–3.0	Dental fluorosis (discoloration, mottling and pitting of teeth)
3.0–4.0	Stiffened and brittle bones and joints
4.0–6.0 and above	Deformities in knee and hip bones and finally paralysis making the person unable to walk or stand in straight posture, crippling fluorosis

Therefore, now there is a need to focus greater attention on the future impact of water resources planning and development taking into consideration all these related issues. As fluoride in drinking water does not change its colour, smell or taste, normally there is no way to detect it unless tested. In recent years, there has been an increased interest in fluoride research because excess concentration of fluoride in drinking water causes adverse impacts on human health. In order to mitigate the excess fluoride in groundwater, it is essential to determine and monitor the causal factors of enrichment of fluoride concentration. Therefore, a systematic assessment of fluoride in groundwater is required for the better management of the fluoride toxicity. Defluoridation of drinking water is the only practicable option to overcome the problem of excessive fluoride in drinking water, where alternate source is not available.

During the years following the discovery of fluoride as the cause of fluorosis, extensive research has been done on various methods for removal of fluoride from water and wastewater. These methods are based on the principle of adsorption[10], ion-exchange[11], precipitation–coagulation[12], membrane separation process[13], electrolytic defluoridation[14], electrodialysis[15], etc. However these techniques are not in much use because of their expensiveness, inefficiency or failure in mass scale application. Several adsorbent materials have been tried in the past to find out an efficient and economical defluoridating agent. Activated alumina, activated carbon, activated alumina coated silica gel, calcite, activated saw dust, activated coconut shell carbon and activated fly ash, groundnut shell, coffee husk, rice husk, magnesia, serpentine, tricalcium phosphate, bone charcoal, activated soil sorbent, carbion, defluoron- 1, defluoron-2, etc., are different adsorbent materials reported in the literature[16-19] but these methods have some limitations as the process has low adsorption capacity, poor integrity and needs pretreatment. Therefore it is aimed to find a suitable low cost environmentally friendly method for removal of fluoride in the drinking water that could be used by common man. Reports on the fluoride removal using algal biomas and tree leaves[20] are available in recent literature and thus a study on adsorption capacity of untreated plant leaves (Tulsi) has been attempted. This technique is easy to understand and can be adopted in rural as well as urban background throughout the year. Other possible negative impacts i.e. handling of dangerous chemicals, consequences of wrong dosing of chemicals and possible chemical residuals were also avoided.

This paper presents a novel way of reducing fluoride content in water samples using optimum amount of Tulsi leaves and time of operation. This locally available tree was chosen as the best option due to its proven medicinal properties. This innovative method can be used in efficient reduction and analysis of fluoride content in water samples and make it safe for further use. The aim of this study was to determine the concentration of a fluoride in the vicinity area of Pratap Nagar. Sanganer, Jaipur and compare it with permissible limits.

Experimental:

The procedure is based on the direct titration of fluoride in aqueous solution with thorium nitrate using sodium alizarinsulphonate as indicator. The titration is carried out at pH 3.3 in the presence of acetic acid. The possibility of interference by SO_4^{-2}, PO_4^{-3}, CO_3^{-2} and HCO_3^- is eliminated by prior treatment of the water with $BaCl_2$ reagent[21]. Determination and then removal of fluoride using Tulsi leaves was performed in the following steps-

Step I- Construction of standard curve

5% solution of 10ml $BaCl_2$ was pipette into the different concentration of standard solutions of sodium fluoride having 1µg, 5µg, 10µg, 20µg, 30µg and 40µg respectively in 100ml of the water in a 150ml conical flask. The solution was boiled, cooled immediately and then filtered. 20 ml of this filtrate was taken in another beaker and 1ml of alizarin solution was added with stirring. The pH of the solution was adjusted with the drop wise addition of 0.05N HCl by observing the color change of the indicator which became yellow-orange. The yellow-orange color is discharged with the addition of 3-4 drops of 0.4N acetic acid. The color of the solution appeared lemon yellow, further 1ml of acetic acid was added.

To remove free chlorine from the above solution, one drop of 0.1N $Na_2S_2O_3$ was added and the mixture was allowed to stand for few minutes and volume was made up to 50ml with distilled water.

The solution was titrated with 0.0004M thorium nitrate solution with constant stirring. The results are computed from a graph (fig. 1) constructed from values obtained by titrating a series of volumes of the standard sodium fluoride solutions as shown in table 2 against a volume of thorium nitrate used.

Step II- Determination of fluoride content in water sample

Amount of fluoride was calculated with the help of standard curve using same methodology as discussed above only standard solution of sodium fluoride was substituted by water sample.

Step III - Determination of fluoride content in water sample after treated with Tulsi leaves

The water sample was treated with 0.5g of Tulsi leaves for 0, 15, 30, 45 and 60 min time and amount of fluoride was again calculated. Similar experiment was also done with 1.0g and 1.5g of Tulsi leaves. The results are presented in table 3.

Results and Discussion:

As discussed in step I, a straight line graph was constructed from the values obtained by titrating a series of volumes of the standard sodium fluoride solutions against a volume of thorium nitrate used. (Table 2)

Table 2 : Readings obtained by the titration between standard sodium fluoride solution and thorium nitrate used

Standard solution	Amount of fluoride (in µg)	Amount of thorium nitrate (in ml)
1	1	0.08
2	5	0.40
3	10	0.80
4	20	1.60
5	30	2.40
6	40	3.21

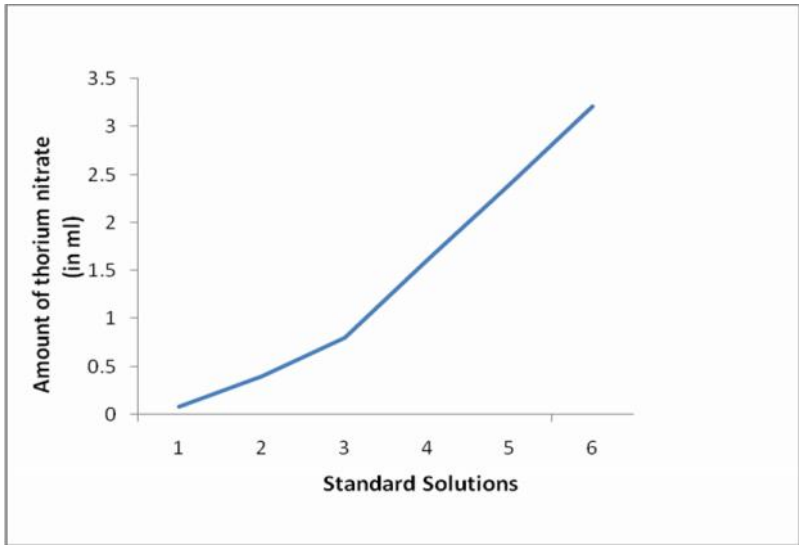

Fig 1: Relation between volume of thorium nitrate used (in ml) and different standard solutions having varied amount of fluoride (in µg).

Further, amount of fluoride was calculated in the water sample taken from Pratap Nagar area of Sanganer, Jaipur with the help of standard curve (fig 1) using same methodology and it was found about 2.35mg/l which is not in the safe limit as set by WHO and responsible for dental flourosis. To remove fluoride from the above sample, two separate experiments were carried out wherein 0.5g and 1.0g of tulsi leaves were treated with one lit of water sample for different period of time and afterwords amount of fluoride was calculated with the help of standard curve. The results are presented in table 3.

Table 3 : % of fluoride removed from 0.5 and 1.0 g of Tulsi leaves

Amount of Tulsi leaves used (in gm)	Time duration of adsorption (in min.)	Amount of Thorium nitrate used (in ml)	Graph reading	Amount of Flouride (in mg/l)	% of Flouride removed
0.5	15	0.9	11.4	1.25	47.06
	30	0.5	6.2	0.68	70.59
	45	0.3	4.4	0.48	82.36
	60	0.42	5.1	0.56	75.30
1.0	15	0.5	6.2	0.68	70.59
	30	0.23	3.0	0.33	85.30
	45	0.45	5.2	0.57	76.48
	60	0.42	5.1	0.56	75.30

The following formula is used for the calculation of fluoride content in water sample.

$$\frac{\text{Graph reading (compared with standard curve)}}{\text{Vol. of } BaCl_2 \text{ used in ml}} \times \frac{110}{100}$$

This Table shows that fluoride content has been efficiently decreased from 2.35mg/l to 0.33mg/l with 1.0g of Tulsi leaves and 30 min as time of operation whereas 0.5g of Tulsi leaves required comparatively greater time i.e. 45min. to decrease 2.35mg/l of fluoride to 0.48mg/l. Similar experiment was also performed with 1.5g of tulsi leaves but no significant decrease in fluoride content was found.

Conclusion:

The literature survey and the laboratory experiments have indicated that plant leaves can remove fluoride under specified conditions. The major highlight of this work is that we have first time used titrimetric method for the determination of fluoride in water sample when Tulsi leaves are used as adsorbent. The fluoride removal efficiency may vary according to many site-specific chemical, geographical and economic conditions. The Tulsi leaves were found to be an efficient adsorbent for the defluoridation of contaminated drinking water sources. The biosorbent was successful in removal of fluoride ions from aqueous solution of 2.35mg/l fluoride concentration with about 85.3% efficiency.

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