To Evaluate Efficacy of Bajra husk and Moringa leaf Powder on Water Defluoridation – A Comparative Study

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Defluoridation, Bajra husk, Moringa leaf, Biochar, TISAB solution, Ion selective electrode

ABSTRACT
Introduction: AIM: To evaluate and compare efficacy of naturally available adsorbents Moringa oleifera and Bajra husk in reducing the fluoride content in the high fluoridated drinking water.
Methodology: A community with high fluoride content in its water was selected and a sample was taken. The baseline fluoride level was determined using an ion selective electrode. Two naturally occurring adsorbents, powdered moringa leaf and bajra husk, were used. The husk and dried leaves were processed, sieved, and heated to 400 degrees Celsius for 30 minutes in a muffle furnace. The water sample was mixed with biochar and agitated for an hour at 500 rpm. Filter paper was used to filter the water sample and added TISAB. The fluoride content of the water sample was estimated using an ion selective electrode approach.
Results: The highest removal of fluoride is significantly done by Moringa leaf biochar (23%) as compared to bajra husk (15%). when 2 grams of this biochar were added in 200ml of water sample separately.
Conclusion: Drinking water defluoridation can be effectively achieved by using moringa leaves and bajra husk as adsorbents. On the other hand, Moring leaf powder proved to be more successful.

1. Introduction

Fluoride (F-) is the 13th most abundant chemical element in the Earth's crust. Dental fluorosis and dental caries are either ends of fluoride concentration in water. so it is often termed as a double-edged sword, as the fluoride ions have dual significance in water supplies. Fluoride concentrations below 0.8 mg/L cause dental caries, while concentrations between 0.8 and 1.0 mg/L are beneficial for calcifying dental enamel (Reddy B S et al., 2016). High fluoride concentrations (> 1.5 mg/L) may cause chronic fluoride toxicity, ranging from mild dental fluorosis to crippling skeletal fluorosis (J Fawell., 2006) Therefore, the most caries protection can be obtained from optimal and prudent use of fluoride, while excessive and imprudent systemic ingestion can result in chronic fluoride toxicity (Reddy B S et al., 2016).

The World Health Organisation (WHO) has determined that drinking water should have a fluoride content of between 0.5 and 1.5 mg/L at a temperature of between 12 and 25°C for general good health. The excess fluoride content is removed from drinking water by process of Defluoridation.

Various defluoridation techniques have been explored which include 1. Adsorption 2. Precipitation/coagulation 3. Ion exchange 4. Membrane processes (Bose et al.,2018) Among the various techniques employed for Defluoridation, Adsorption is a popular method because of its low cost, simplicity, and convenience of use, high removal capacities, and ability to reuse the adsorbent which makes it a desirable choice (Dar et al., 2023)

Various adsorbents have been used for defluoridation, e.g., from natural sources (such as those derived from various biomasses), natural alternatives (such as clay-type minerals) and industry produced (e.g., activated carbon) (Chiavola et al., 2022). Activated carbon is one of the frequently used adsorbents. Because of its larger surface area, microporous capabilities, and chemical complexity, it has a high potential for heavy metal adsorption (Ahmad et al., 2019). Various carbonaceous materials and agricultural by-products have been investigated for their potential to remove fluoride from water, highlighting their effectiveness in defluoridation.

The goal of this work is to assess the Bajra husk's (Pennisetum glaucum) [figure 1a] as deflouridation effectiveness because it has the potential to be used as an active bio adsorbent. Bajra is also known as pearl millet and is widely consumed as a staple food in rural Rajasthan, Maharashtra, Haryana, Uttar Pradesh, and Gujarat. It contains lignocellulosic material, which provides active sites that can bind with fluoride ions, effectively reducing their concentration in water. The use of Bajra husk is considered a low-cost and sustainable approach for water treatment, particularly beneficial in rural areas. (Rahman et al., 2022)..

Moringa oleifera [figure 1b] Moringa leaf powder is used as a natural adsorbent for defluoridation due to its high affinity for fluoride ions. The leaves contain active compounds like hydroxyl and carboxyl groups that can bind to fluoride, effectively reducing its concentration in water. This method is eco-friendly, cost-effective, and provides an accessible solution for fluoride removal, especially in regions with limited access to advanced water treatment technologies (Milla PG et al, 2021).

This study has been designed to assess Bajra husk and moringa leaf in deflouridation.


(a) (b)

Figure 1 :(a) Bajra , (b): Moringa leaf powder

2. Methods and Materials

2.1. Water sample collection

Vadloor is a village in Raichur district of Karnataka is noted as high flouridated area and the sample water showed 8.5 ppm of fluoride by using ion selective electrode [figure 2]

Figure 2: Ion selective electrode

2.2. Adsorbent collection and powder preparation

Moringa oleifera leaves and Bajra husk, naturally occurring adsorbents, were gathered. Moringa oleifera leaves were air-dried in the shade for a period of five days, while Bajra husk underwent a similar shade-drying process for three days. Subsequently, both were finely powdered using a mixer grinder and sifted through a 100 mm sieve.

2.3. Preparation and mixing of biochar

Both Moringa and Bajra powders are placed separately in muffle furnace at 400 degree Celsius (Figure:3). Because at this temperature volatile compounds are released, and the carbon content of the material increases, enhancing its surface area and porosity, which is crucial for efficient fluoride adsorption. The procedure is carried out for 30 minutes which is sufficient to ensure that the pyrolysis process is complete, allowing for the transformation of the biomass into biochar. 2grams of prepared biochar is mixed with sample water separately in different containers. These containers placed on magnetic stirrer for 1 hour at 500 rpm. Then the prepared sample water was incubated for 24 hours. Subsequently water sample was filtered by using whatsman filter paper.

Figure 3: Muffle furnace

2.4 Estimation of fluoride in prepared sample

To this water sample total [ionic strength](#) adjustment buffer solution TISAB solution was added. TISAB III (Orion 940911)(Figure:4) adjusts ionic strength, buffers pH to 5 to 5.5, and contains a chelating agent to break up metal-fluoride complexes. It is sent to the fluoride estimation by using ion selective electrode.

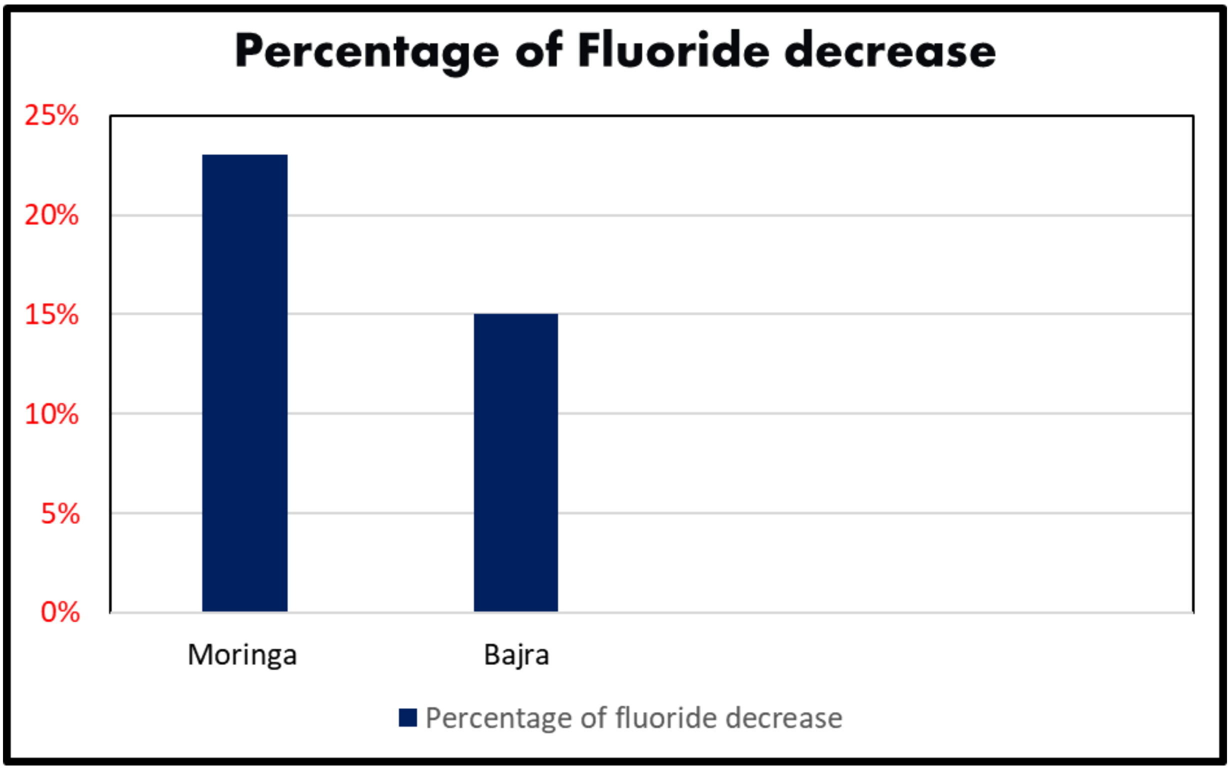
Figure 4: TISAB

3. Results

The Moringa leaf biochar demonstrated a higher efficacy, reducing fluoride content by 23% when 2 grams of biochar were added to 200 ml of sample water [Table 1]. On the other hand, Bajra husk biochar exhibited a 15% reduction under the same conditions [Table 1]. These findings suggest that both adsorbents have potential for use in defluoridation, with Moringa leaf biochar proving to be more successful in this particular study. [graph 1]

Table 1: showing percentage of reduction of fluoride

Moringa Oleifera Leaf					
Sl no	Adsorption dosage (grams)	Water sample	Initial Fluoride level (ppm)	Final Fluoride level(ppm)	Percentage of Fluoride decrease (%)
1	2gms	200ml	8.5	6.2	23%
Bajra Husk					
Sl no	Adsorption dosage (grams)	Water sample	Initial Fluoride level (ppm)	Final Fluoride level(ppm)	Percentage of Fluoride decrease (%)
1	2gms	200ml	8.5	7.2	15%



Graph 1: Graph showing level of reduction of fluoride

4. Discussion

Fluoride is the ionic form of fluorine, naturally released in air and water. Tea, seafood, medical supplements, and fluoridated toothpastes are also substantial sources of fluoride. Fluoride compounds are additionally produced by various industrial processes using the mineral apatite, a combination of calcium phosphate compounds. Groundwater has a higher fluoride concentration because of longer contact durations with fluoride-bearing minerals. Human activities such as the aluminium and coal industries, fertiliser use, and manufacturing processes all contribute to fluoride dispersal in to ground water. Since it is one of the most essential natural sources of drinking water, pollution by fluoride is an ongoing global concern due to its toxicity, which has adverse consequences for human health (Shaji et al., 2024). Fluoride prevents dental caries and aids bone mineralization, but excessive consumption leads to fluorosis, a condition linked to serious illnesses like thyroid disorders, Alzheimer's, osteoporosis, and cancer (Fadaei et al., 2021). Recent studies have demonstrated that fluoride can cause oxidative stress, alter lipid peroxidation, protein carbonyl content, intracellular redox homeostasis, gene expression, and trigger apoptosis (Barbiero et al., 2010). Researchs also suggests that high consumption of fluoridated water may have more detrimental effect on children's IQ and cognitive development (Shivaprakash et al., 2011)

Defluoridation is a major global challenge that aims to remove fluoride ions from drinking water. Various defluoridation techniques include: 1. Adsorption technique 2. Ion-exchange technique 3. Precipitation technique 4. Other techniques, that include electro chemical defluoridation and Reverse Osmosis (Jamwal et al., 2022). Materials used in these techniques are presented in. Despite of many efforts, the primary challenge is to develop a cost-efficient and effective technique for removing fluoride from drinking water, particularly for poor and marginalized groups living in underdeveloped regions or areas with limited access to alternatives (Chen et al., 2014). Of the above techniques, adsorption method is the most efficient, feasible and cost-effective. The process of adsorption is defined as the transfer of ions via various processes from the solution phase to the solid phase. It involves chemisorption and physical adsorption by a wide range of techniques, including ion exchange, complexation, and chelation (Kumar et al., 2021). Chen et al. in their study observed that the Fe–Al granular ceramic could adsorb fluoride up to a maximum of 96% (Chen et al., 2014). The highest fluoride adsorption capacity using activated alumina was 1.45 mg/g at pH 7, and the highest fluoride removal capacity utilising ash adsorbent was 332.5 mg/g. There are several adsorbents that can be used to defluoridate drinking water, they are primarily divided into two categories: inorganic and organic. Bio-adsorption is the process of binding and concentrating metals from diluted aqueous solutions using specific biomass (Sudaryanto et al., 2006). New bioadsorbents are being investigated by researchers as they are biodegradable, affordable, and renewable fluoride mitigation methods. These options outperform traditional treatments because of their easier designs, low costs, higher efficiency, and ease of recycling (Rahman et al., 2022).

Activated carbon has a complex porous structure with associated energetic as well as chemical in homogeneities. Its huge specific surface area and developed micropores contribute to its great absorptivity and large adsorption capacity (Sudaryanto et al., 2006). Since biochar is affordable, energy-efficient, and environmentally benign, it's a viable solution for eliminating heavy metal contamination (Biswas et al., 2023).

Considering all the perks mentioned above, in the present study, we opted for the adsorption technique using biochar which includes high removal capacities, reusability of the adsorbent, ease of use, and cost effectiveness.

Moringa, a native plant from Africa and Asia, and the most widely cultivated species in Northwestern India. The plant is cultivated for its nutrient-dense pods, edible leaves, and fragrant blooms, used in medicine, food, cosmetic oil, and animal feed due to its rich vitamins and antioxidants like flavonoids, alkaloids, glucosinolates (Vergara-Jimenez et al., 2017). As a major coagulant for water treatment, powder made from Moringa oleifera seeds has proven to be one of the most successful plant materials studied over the years. The leaf biochar of this plant was used as a potential material for defluoridation of drinking water and also tested for antibacterial activity. According to Jiraungkoorskul et al, different parts of M. oleifera, such as the seeds, leaves, and bark, show excellent surface area and porosity in their morphological structure for the adsorption of contaminants, making them promising biosorbents for fluoride removal (Jiraungkoorskul et al). Study conducted by Laney et al compared Moringa seeds powder with alumina and reported that Moringa seeds powder was more effective than any other plant material tested over the years for treating water (Laney et al., 2020).

Bajra/ Pearl millet (Pennisetum glaucum), is a cereal of the Poaceae family that grows in tropical and subtropical regions of the world and is a staple crop in Asia and Africa. Bajra may be utilised as a bioremediation plant since it contains hydrolysates and peptides with bioactive peptide-rich protein. The interaction between peptide and metal species may be enhanced by the presence of hydrophobic amino acids (Dubey et al., 2017). Successful heavy-metal adsorption products frequently comprise of lignocellulosic biomass and acidic groups like carboxylic and phenolic compounds. Bajra was chosen as a bio adsorbent in this study, owing to its high cellulose content and carboxylic acids.

Results of the present study reported that Moringa leaves powder retained 23% of fluoride from the drinking water.

Whereas Bajra Husk showed 15% reduction in the fluoride from drinking water this was similar to the results obtained by Rahman et al where he reported that Bajra husk had 89% capacity to retain fluoride from drinking water (Rahman et al., 2022).

5. Conclusion

Moringa leaves and Bajra husk are effective bio adsorbents in removing fluoride from drinking water. When compared, Moringa leaves were more effective than bajra husk in reducing fluoride levels. Further studies using larger quantities are necessary to more accurately evaluate the effectiveness of Moringa and Bajra biochar in fluoride removal.

References:

[1] Reddy BS, Parameshwar KS. Water quality studies of Saralasagar reservoir with reference to physico–chemical parameters. Indian Journal of Science and Technology. 2016 Aug;9(29):1-8.

[2] J. Fawell, K. Bailey, E. Chilton, E. Dahi, L. Fewtrell, Y. Magara, Fluoride in Drinking 865 Water, World Health Organization, IWA Publishing, UK, 2006.

[3] Bose S, Yashoda R, Puranik MP. A review on defluoridation in India. International Journal of Applied Dental Sciences. 2018; 4:167-71.

[4] Dar FA, Kurella S. Recent advances in adsorption techniques for fluoride removal–An overview. Groundwater for Sustainable Development. 2023 Sep 29:101017.

[5] Chiavola A, D'Amato E, Di Marcantonio C. Comparison of Adsorptive Removal of Fluoride from Water by Different Adsorbents under Laboratory and Real Conditions. Water. 2022 Apr 29;14(9):1423.

[6] Ahmad A, Azam T. Water purification technologies. In Bottled and Packaged Water 2019 Jan 1 (pp. 83-120). Woodhead Publishing.

[7] Rahman MA, Bar S, Parwani L. Removal of fluoride from drinking water to permissible levels with Bajra husk. Materials Today: Proceedings. 2022 Jan 1; 68:1158-66.

[8] Shaji E, Sarath KV, Santosh M, Krishnaprasad PK, Arya BK, Babu MS. Fluoride contamination in groundwater: A global review of the status, processes, challenges, and remedial measures. Geoscience Frontiers. 2024 Mar 1;15(2):101734.

[9] Fadaei A. Comparison of water defluoridation using different techniques. International Journal of Chemical Engineering. 2021 Nov 26; 2021:1-1.

[10] Barbier O, Arreola-Mendoza L, Del Razo LM. Molecular mechanisms of fluoride toxicity. Chemico-biological interactions. 2010 Nov 5;188(2):319-33.

[11] Shivaprakash PK, Ohri K, Noorani H. Relation between dental fluorosis and intelligence quotient in school children of Bagalkot district. Journal of Indian Society of Pedodontics and Preventive Dentistry. 2011 Apr 1;29(2):117-20.

[12] Jamwal KD, Slathia D. A review of defluoridation techniques of global and indian prominence. Current World Environment. 2022;17(1):41-57.

[13] Chen N, Feng C, Li M. Fluoride removal on Fe–Al-impregnated granular ceramic adsorbent from aqueous solution. Clean Technologies and Environmental Policy. 2014 Mar; 16:609-17

[14] Kumar A, Balouch A, Abdullah. Remediation of toxic fluoride from aqueous media by various techniques. International Journal of Environmental Analytical Chemistry. 2021 Mar 16;101(4):482-505.

[15] Sudaryanto Y, Hartono SÁ, Irawaty W, Hindarso H, Ismadji S. High surface area activated carbon prepared from cassava peel by chemical activation. Bioresource technology. 2006 Mar 1;97(5):734-9.

[16] Biswal BK, Balasubramanian R. Use of biochar as a low-cost adsorbent for removal of heavy metals from water and wastewater: A Review. Journal of Environmental Chemical Engineering. 2023 Sep 9:110986.

[17] Vergara-Jimenez M, Almatrafi MM, Fernandez ML. Bioactive components in Moringa oleifera leaves protect against chronic disease. Antioxidants. 2017 Nov 16;6(4):91

[18] Milla PG, Peñalver R, Nieto G. Health benefits of uses and applications of Moringa oleifera in bakery products. Plants. 2021 Feb 6;10(2):318.

[19] Laney B., Rodriguez-Narvaez O. M., Apambire B. & Bandala E. R. 2020 Water defluoridation using sequentially coupled Moringa oleifera seed extract and electrocoagulation. Groundwater Monitoring and Remediation 40 (3), 67–74

[20] Dubey L, Sharma HK, Khare RK. Removal of Zinc and Lead from Aqueous Solution using Low Cost Bioadsorbent Pennisetum glaucum (Bajara) Husk. Advances in Bioresearch. 2017 Jul 1;8(4).