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Defluoridation of water with the Help of Azadirachta Indica, Fecus Recemosa and Feronia Limonia leaves as Bioadsorbents

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ABSTRACT

Depending on the nature of the processes, the defluoridation approach used thus far has included adsorption, precipitation, electrochemical, ion exchange, and membrane approaches. However, due to their high cost, inefficiency, or failure in large-scale applications, these approaches are not frequently employed. As a result, finding an excellent low-cost and ecologically acceptable approach for removing fluoride from drinking water is critical. In this study, neem (Azadirachta indica) leaf powder, gular (Fecus recemosa) leaf powder, and kaith (Feronia limonia) leaf powder were used as low-cost bioadsorbents for fluoride removal from water. For adsorption isotherms, several models have been employed to explain experimental data. However, the Langmuir, Freundlich, and Temkin isotherm models are appropriate for this investigation. The SEM & EDX examined of groundwater sample with Azadirachta indica, Ficus recemosa, and Feronia limonia leaves powder after and before treatment.

Keywords: Defluoridation, Fecus Recemosa, Feronia Limonia, SEM

1. INTRODUCTION

For more than a century, scientists worldwide have examined the effects of fluoride poisoning on human health. Depending on the degree of exposure, fluoride has both positive and negative effects on the human body. According to Ozsvath (2009) research, ingestion of a moderate amount of fluoride can effectively reduce the incidence of dental caries and stimulate the building of strong bones under specific conditions (Ajisha and Rajagopal, 2013, Chaudhry *et al.*, 2017, Canciam and Pereira, 2019, Bai *et al.*, 2019, Contoral *et al.*, 2019). Fluoride exposure over time can result in dental fluorosis and skeletal fluorosis (Jagtap *et al.*, 2012 and Jimennez-Farfan *et al.*, 2011), an increase in the rate of urolithias, and a drop in natality and IQ in children. Chronic exposure may cause various problems, including genetic mutations, birth deformities, and Alzheimer's disease; however, scientific evidence is still unclear (Araga *et al.*, 2019, Alhassan *et al.*, 2020). The maximum amount of fluoride in drinking water advised by the World Health Organization (WHO, 2011) is 1.5 mgL^{-1}.
Clean water is, as we all know, one of our most fundamental necessities. Fluoride concentration in drinking water grows due to many sources, resulting in the above-mentioned negative consequences (Fujita and Suzuki, 2013, He *et al.*, 2015, Fito *et al.*, 2019 and Egor and Birungi, 2020). It may be best to avoid that specific source as a temporary remedy. In-situ and ex-situ technologies that decrease fluoride content and convert it to a helpful state are used to remediate fluoride-contaminated groundwater. Adsorption is one of the most practical and cost-effective fluoride removal technologies (Gong *et al.*, 2012, He *et al.*, 2015, Haung *et al.*, 2017). This method involves passing water over a contact bed and adsorbing fluoride onto the matrix. Fluoride concentration, contact duration, pH, adsorbent size, and type play a role in effective removal. The saturated column or bed should be replenished or regenerated after a period of time. Around 1930, activated alumina was used for the first defluoridation. It is built of porous aluminium oxide and has a vast surface area. The continuous aluminium lattice creates a confined positive charge region, making it a suitable adsorbent for many anionic adsorbates. It is commonly employed in defluoridation because it has a higher selectivity for fluoride ions than other ions.

Activated charcoal, fly ash, activated aluminium, serpentine, charfines; brick, bone char, red mud, waste mud, kaolinite, rice husk, bentonite, ceramic, and other adsorbents are some of the most effective fluoride adsorbents (Cui *et al.*, 2012, Dong and Wang, 2016, Demelash *et al.*, 2019).

In this study, neem (*Azadirachta indica*) leaf powder (Kashyap et al., 2022), gular (*Fecus recemosa*) leaf powder (Meena et al., 2021), and kaith (*Feronia limonia*) leaf powder (Meena et al., 2022) were used as low-cost bioadsorbents for fluoride removal from water. Neem commonly known as nim or margosa is a fast-growing tree of the mahogany family prized for its organic insecticides, medical properties, and lumber. Neem is most likely native to the India and Indian subcontinent and drier parts of South Asia. It has multiplied to areas of Africa, the Caribbean, and several Central and South American nations. The plant has long been employed in Ayurvedic and traditional medicine, organic farming, and cosmetics. *Ficus racemosa*, often known as the cluster fig, red river fig, or gular, is a plant species in the Moraceae family. Its natural range includes Australia and tropical Asia.

It is a fast-growing plant with broad, rough leaves that can grow to the size of a large shrub, while older examples can get very massive and twisted. It is uncommon that its figs grow on or near the tree stem, a condition known as cauliflory. After the seeds have been removed, the fruits are typically consumed as a vegetable in stir-fries and curries. The fruits are a favourite food of the Indian macaque. It is a feeding plant for the caterpillars of northern Australia's two-brand crow butterfly (Euploea Sylvester). Kapittha or kaitha (wood apple) is an Ayurvedic plant used to relieve nausea and vomiting and as an antidote to several toxins. It increases taste perception, strengthens cardiac muscles, and clears mucus from the throat, which causes dyspnea and thirst. *Acidissima Limonia Limonia acidissima, Feronia limonia Linn*.

2. MATTERIALS AND METHODS

Preparation of Bioadsorbents

a. Neem (*Azadirachta Indica*) Leaf Powder: *Azadirachta Indica* leaves were used as the cheap natural adsorbent. These were sourced from behind the university campus. The neem leaves were dried, pulverized, and washed thoroughly with DDW (Double Distilled Water). They were dried in an oven at 60 – 90°C for 24 hours, after which the dried material was pulverized in a pulveriser and screened into 25-50 μm mesh ASTM (Kashyap et al., 2022).

Alkali Treatment: A leaf powder sample of 40 gm and 400 ml of 0.5 N NaOH were mixed in a 1 L flask. The mixed liquid was heated for 20 minutes after it began to boil. DDW was used to rinse the treated biomass until the most intense colour was removed and clear water was obtained.

b. Gular (*Fecus Recemosa*) Leaf Powder: *Ficus recemosa* leaves are collected from a healthy tree, cleaned with DDW, and then dried in the sun for 2-4 days (Meena et al., 2021). Grind the dried leaves using a mixer and screen them with a sufficient mesh size for examination.

c. Kaith (*Feronia Limonia*) Leaf Powder: The leaves of the Kaith plant (*Feronia limonia*) are readily available; they are picked, cleaned many times with DDW, and then dried in the sun for 2-4 days. Using a mixer, grind the dried leaves and screen them to an appropriate mesh size for examination (Meena et al., 2022).

Standard Fluoride Solution

221 mg of NaF was dissolved in 1 L of DD water to make a fluoride stock solution with a concentration of 100 mg/L. Using appropriate dilution, a 10 mg/L solution was made from the stock solution.

3. RESULTS AND DISCUSSIONS

Fluoride removal from a water sample was monitored using a Fluoride Ion Meter Panamax (Model PX/IMC/321). It is calibrated first using 100 and 10 mgL^{-1} solutions made from the stock solution. The plastic beaker is rinsed with tap water before being cleansed again with DDW. In a 250 mL plastic beaker, 100 mL of 10 mgL^{-1} water solutions were added, at the proper pH, 0.5 N HNO_3 was added, and 10 g/L of adsorbent was stored for 30-120 minutes at room temperature (27°C ± 0.5°C). The solution collects readings of this sample at different time intervals after a 30- 120 minutes filter. For additional observations, it employs several factors such as pH, adsorbent dosage, and adsorbent contact duration (Birhanu et al., 2020).

(i) Effect of Initial Adsorbate Concentration: By increasing the initial concentration (Ci) of F^- from 2 to 10 mgL^{-1}, the adsorption performance of treated bioadsorbents was investigated methodically. The efficiency of removing F^- varies depending on the initial concentration of F^- aqueous solution (100 mL). The initial fluoridated aqueous solution with an adsorbent dose of 10 gL^{-1}, the pH of 2, the contact period of approximately 2 hours, and the temperature adjusted to 27°C ± 0.5°C (room temperature). As indicated in table 1.0 and figure 1.0, the treated adsorbents were moderately active in reducing fluoride ions, recorded was 93 to 79% for a*zadirachta indica* , 71 to 49.2% for *fecus recemosa*, and 51.3 to 43.5% for *feronia limonia*. During the adsorption process, it was observed that increasing the initial concentration of fluoridated water resulted in decreasing in adsorption efficiency.

Table 1: The Efficiency of Removing F⁻ on the Initial Concentration of the Fluoridated Aqueous Solution for Different Bioadsorbents

In the initial fluoridated adsorbate solution operating order, the adsorbent dosage was 10 g/L, the temperature was set to 27°C ± 0.5°C, the contact time was 120 minutes, the sample volume was 100 ml, and the pH was 2.							
SN	Ci (mg/L)	For *Azadirachta indica*		For *Fecus recemosa*		For *Feronia limonia*	
		Ce (mg/L)	Removal % of F^-	Ce (mg/L)	Removal % of F^-	Ce (mg/L)	Removal % of F^-
1	2.0	0.14	93	0.58	71	0.99	51.30
2	4.0	0.36	91	1.40	65	1.78	46.40
3	6.0	0.84	86	3.18	53	3.17	48.20
4	8.0	1.52	81	3.96	49.5	4.40	45
5	10.0	2.10	79	4.92	49.2	5.65	43.50

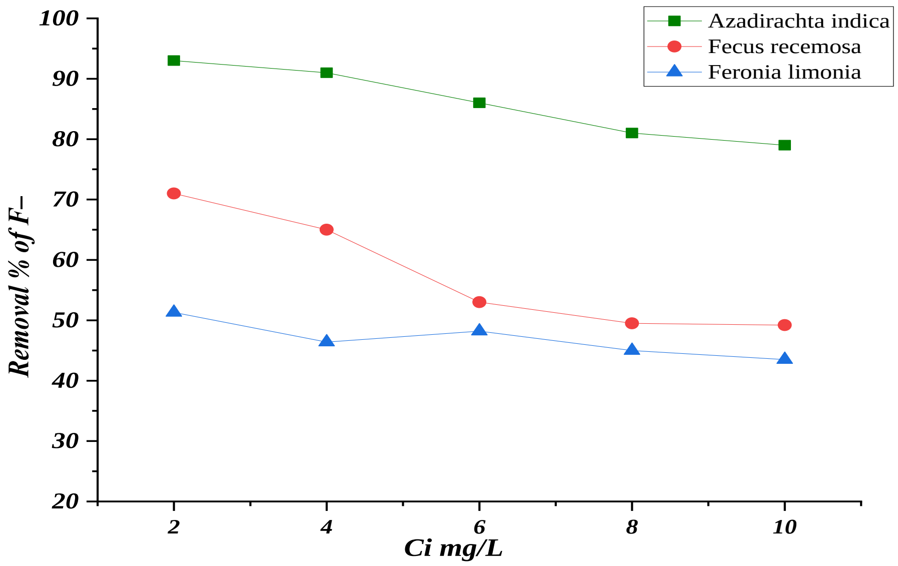


Figure 1: Removal (%) of F⁻ with Initial Concentration (Ci) of Adsorbate

Adsorption Isotherm Model Studies: Adsorption studies are required to describe the adsorption process adequately. For adsorption isotherms, several models have been employed to explain experimental data. However, the Langmuir, Freundlich, and Temkin isotherm models are appropriate for our investigation (Kinniburgh, 1986; Yuan et al., 2020; Philip et al., 2021; Ali and Ismail, 2021).

The parameters derived from various models give essential information about the adsorption process and adsorbent affinity. By analysing the correlation coefficient, linear regression is usually employed to select the best-fitted isotherm. The characteristics derived from various models give crucial information about the adsorption mechanism as well as the adsorbent's affinity. By analysing the correlation coefficient, linear regression is usually employed to select the best-fitted isotherm.

- **Langmuir Isotherm:**

$$\frac{C_e}{q_e} = \frac{1}{q_m} C_e + \frac{1}{K_a q_m}$$

Where C_e is the equilibrium concentration of adsorbate, q_e denotes the quantity of adsorbed per gram of the adsorbent at equilibrium, K_a represents the Langmuir isotherm constant in L/mg, and q_m is the highest adsorption capacity of the adsorbent**.** As shown in Table 2 and figure 2.

- **Freundlich Isotherm:**

$$\log q_e = \log K_f + \frac{1}{n} \log C_e$$

Where is K_f is the Freundlich isotherm constant, n indicates the adsorption intensity. As shown in Table 2 and figure 3 (Priyantha and Kotabewatta 2019).

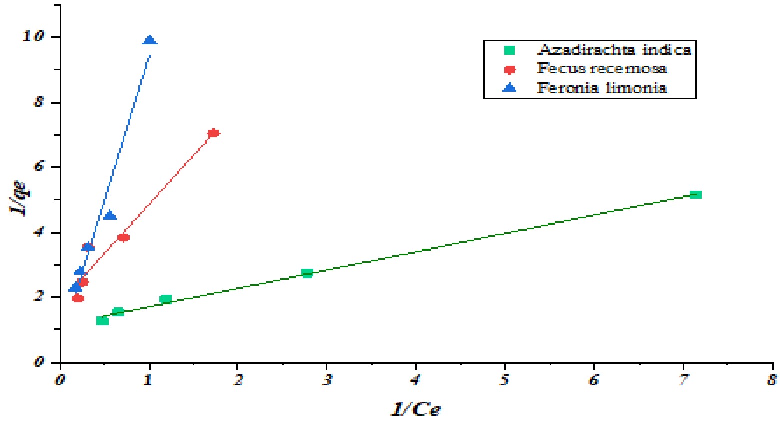


Figure 2: For the Employed Defluoridation Aqueous Solution, a Langmuir Isotherm Plot was Observed Fitted for Azadirachta Indica, Fecus Recemosa, and Feronia Limonia Leaves as Bioadsorbents.

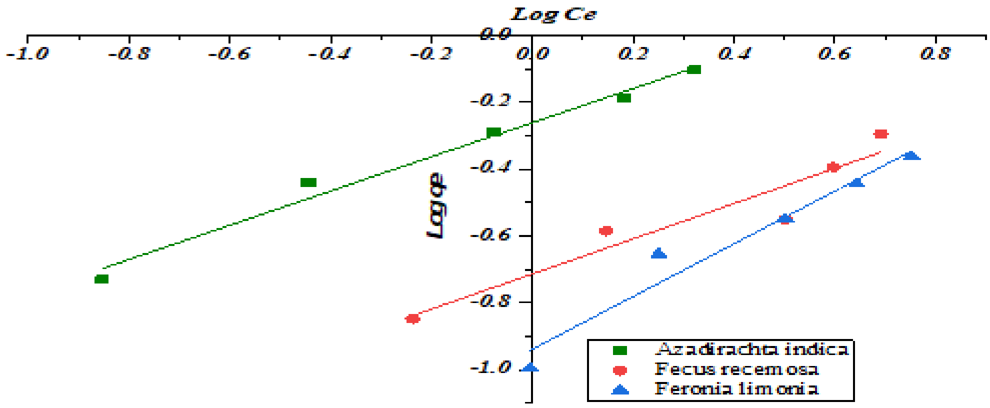


Figure 3: For the Employed Defluoridation Aqueous Solution, a Frenudlich Isotherm Plot was Observed Fitted for Azadirachta Indica, Fecus Recemosa, and Feronia Limonia Leaves as Bioadsorbents.

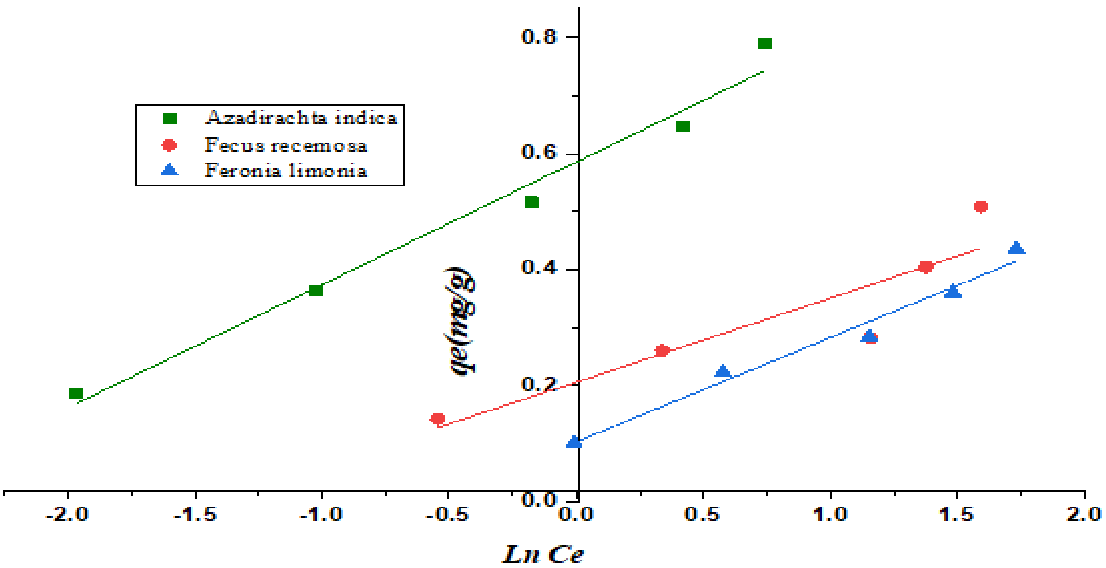


Figure 4: For the Employed Defluoridation Aqueous Solution, a Temkin isotherm Plot was Observed Fitted for Azadirachta Indica, Fecus Recemosa, and Feronia Limonia Leaves as Bioadsorbents.

- **Temkin Isotherm**

$$q_e = \frac{Rt}{b} \ln K_T + \frac{RT}{b} \ln C_e$$

Where b is Temkin constant which is related to heat of sorption, and K_T is Temkin isotherm constant. As shown in Table 2 and figure 4 (Altun et al., 2021; Kashyap et al., 2022).

Table 2: Different Isotherm Parameters and their Values for Different Bioadsorbents for the used Defluoridation Aqueous Solution

Isotherms parameters from different isotherm models						
For *Azadirachta indica*	**Langmuir isotherm**		**Freundlich isotherm**		**Temkin isotherm**	
	q_m (mg/g)	0.8714445	K_f ($mg^{1-(1/n)}$ $L^{l/n}$ g^{-1})	0.54875	B_T (J mol^{-1})	0.21221
	K_a (L/mg)	2.033168	l/n	0.5113	K_T (L mg^{-1})	15.8235
	R^2	0.99605	R^2	0.98327	R^2	0.98075
For *Fecus recemosa*	**Langmuir isotherm**		**Freundlich isotherm**		**Temkin isotherm**	
	q_m (mg/g)	0.5440844	K_f ($mg^{1-(1/n)}$ $L^{l/n}$ g^{-1})	0.19356	B_T (J mol^{-1})	0.14502
	K_a (L/mg)	0.608702	l/n	0.52634	K_T (L mg^{-1})	4.12662
	R^2	0.94602	R^2	0.9105	R^2	0.82676
For *Feronia limonia*	**Langmuir isotherm**		**Freundlich isotherm**		**Temkin isotherm**	
	q_m (mg/g)	1.80675	K_f ($mg^{1-(1/n)}$ $L^{l/n}$ g^{-1})	0.115393	B_T (J mol^{-1})	0.17982
	K_a (L/mg)	0.062643	l/n	0.78708	K_T (L mg^{-1})	1.77094
	R^2	0.96511	R^2	0.95494	R^2	0.97718

(ii) Effect of Contact Time: The experiment consisted of 100 mL of initial fluoridated aqueous solution (10 mg/L) with an adsorbent dose of 10 g/L, the pH of 2, and the temperature was adjusted to 27°C ± 0.5°C (room temperature). As indicated in table 3 and figure 5, with increasing the contact duration (t) of fluoridated aqueous solution (adsorbate) with adsorbents from 30 to 150 minutes, the treated adsorbents with contact time F^- were reduced by 53 to 79% for a*zadirachta indica* (neem), 21.6 to 53.4% for *fecus recemosa* (gular), and 19.2 to 56.3% for *feronia limonia* (kaith). During the adsorption process, it was observed that increasing the time duration of fluoridated water with adsorbents increased adsorption efficiency.

Table 3: The Efficiency of Removing F^- on the Contact time Duration of the Fluoridated Aqueous Solution and Different Bioadsorbents

In the contact time operating order, the temperature was set to 27°C ± 0.5°C, the adsorbent dosage was 10 g/L, Ci = 10 mg/L, pH was 2, and the sample volume was 100 ml.								
SN	Time (min.)	Ci (mg/L)	For *Azadirachta indica*		For *Fecus recemosa*		For *Feronia limonia*	
			Ce (mg/L)	Removal % of F^-	Ce (mg/L)	Removal % of F^-	Ce (mg/L)	Removal % of F^-
1	30	10	4.6	53.9	7.84	21.6	8.08	19.2
2	60	10	3.8	61.9	6.76	32.4	7.14	28.6
3	90	10	2.72	72.8	6.0	40	6.69	33.1
4	120	10	2.1	79	4.92	49.2	5.65	43.5
5	150	10	2.1	79	4.66	53.4	4.37	56.3

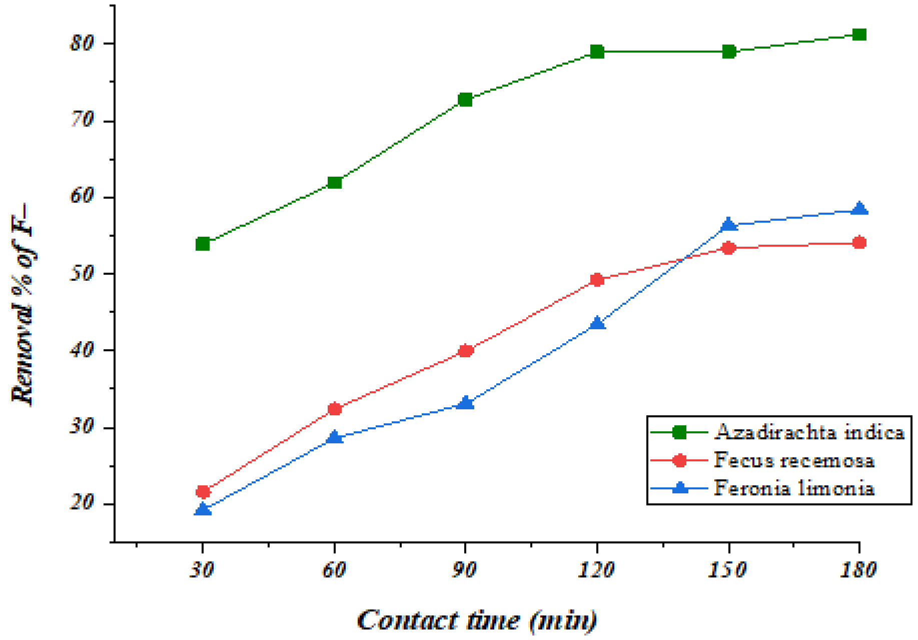


Figure 5: Removal (%) of F⁻ with Contact time (t) of Adsorbet and Adsorbents

Kinetic Studies: A chemical kinetics study is necessary to identify the reaction's rate constants and how rapidly or slowly the reaction is progressing. As a result, it is revealed that the pseudo-second-order kinetics in figure 6 is more appropriately characterized under this research system, which was based on the premise that the rate-limiting process may be physisorption owing to weak forces of attraction between adsorbent and adsorbate.

- **Pseudo-first-order rate:** Equation is represented by follows:

$$\log\left(q_e - q_t\right) = \log q_e - \frac{K_1 t}{2.303}$$

Where q_t and q_e are the total of fluoride adsorbed at contact time t and at equilibrium respectively and k_1 is the pseudo-first-order rate constant. Pseudo-first-order rate constant k_1 and the equilibrium adsorption capacity q_e were determined from the slope and intercept of the plots of log $(q_e - q_t)$ against time are shown in figure 6 and table 4 along with the correlation coefficient (R^2).

- **Pseudo-second-order rate:**

The rate-determining step is the pseudo-second-order kinetic model, which may be represented as:

$$\frac{t}{q_t} = \frac{1}{k_2 q_e^2} + \frac{1}{q_e} t$$

Where k_2 denotes the adsorption rate, q_t is the total amount of F^- adsorbed at any given time, and qe denotes the equilibrium adsorption capacity. The slope and intercept of the plot of t/qt against t displayed in figure 7, as well as the kinetic data in table 4 (Wolowicz and Wawrzkiewicz, 2021).

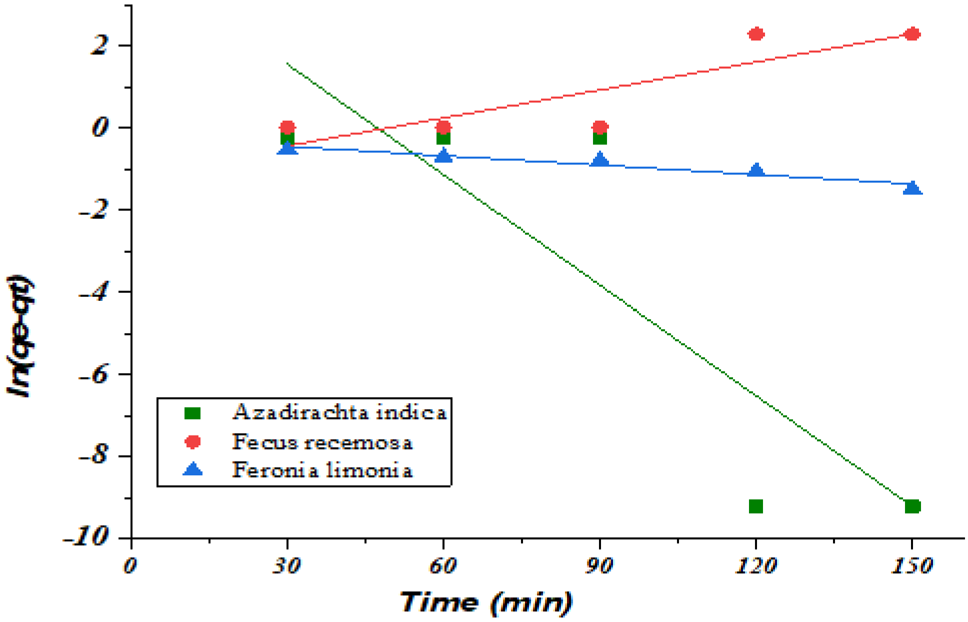


Figure 6: For the Employed Defluoridation Aqueous Solution, Pseudo 1st Order Rate Plot was Observed for *Azadirachta Indica*, *Fecus Recemosa*, and F*eronia Limonia* Leaves as Bioadsorbents.

Table 4: Kinetic Parameters and their Values for Different Bioadsorbents for used Defluoridation Aqueous Solution

Kinetic parameters				
	Pseudo-1st-order		**Pseudo-2nd-order**	
For *Azadirachta indica*	q_e (mg/g)	70.2169	q_e^2 (mg/g)	0.858610
	K_1 (min^{-1})	-0.00015	K_2 (g/mg/min.)	0.03250
	R^2	0.750	R^2	0.99425
	Pseudo-1st -order		**Pseudo-2nd order**	
For *Fecus recemosa*	q_e (mg/g)	0.328502	q_e^2 (mg/g)	0.801697
	K_1 (min^{-1})	0.0001518	K_2 (g/mg/min.)	0.007112
	R^2	0.750	R^2	0.97119
	Pseudo-1st -order		**Pseudo-2nd -order**	
For *Feronia limonia*	q_e (mg/g)	0.808172	q_e^2 (mg/g)	1.096985
	K_1 (min^{-1})	-5.08667	K_2 (g/mg/min.)	0.007307
	R^2	0.92178	R^2	0.75609

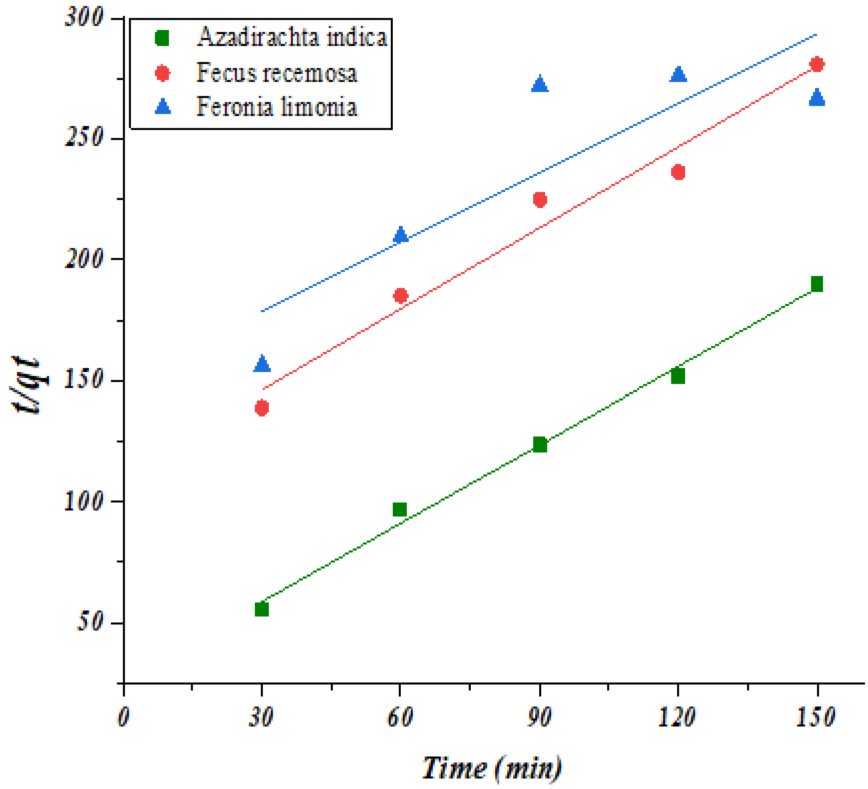


Figure 7: For the Employed Defluoridation Aqueous Solution, Pseudo 2nd Order Rate Plot was Observed Fitted for *Azadirachta Indica*, *Fecus Recemosa*, and F*eronia Limonia* Leaves as Bioadsorbents.

(iii) Effect of pH: The experiment consisted of 100 mL of initial fluoridated aqueous solution (10 mg/L) with an adsorbent dose of 10 g/L, for 2 hours, and the temperature was adjusted to 27°C ± 0.5°C (room temperature). As indicated in table 5 and figure 8, with increasing the pH from 2 to 10 of fluoridated aqueous solution (adsorbate), the treated adsorbents and recorded fluoride ions elimination efficiency decreased by 79 to 59% for leaf powder of azadirachta indica (neem). The process of adsorption of fluoride ions with fluoridated water with powder of fecus recemosa (gular) and feronia limonia (kaith) leaves first increased with increasing pH, then decreased.

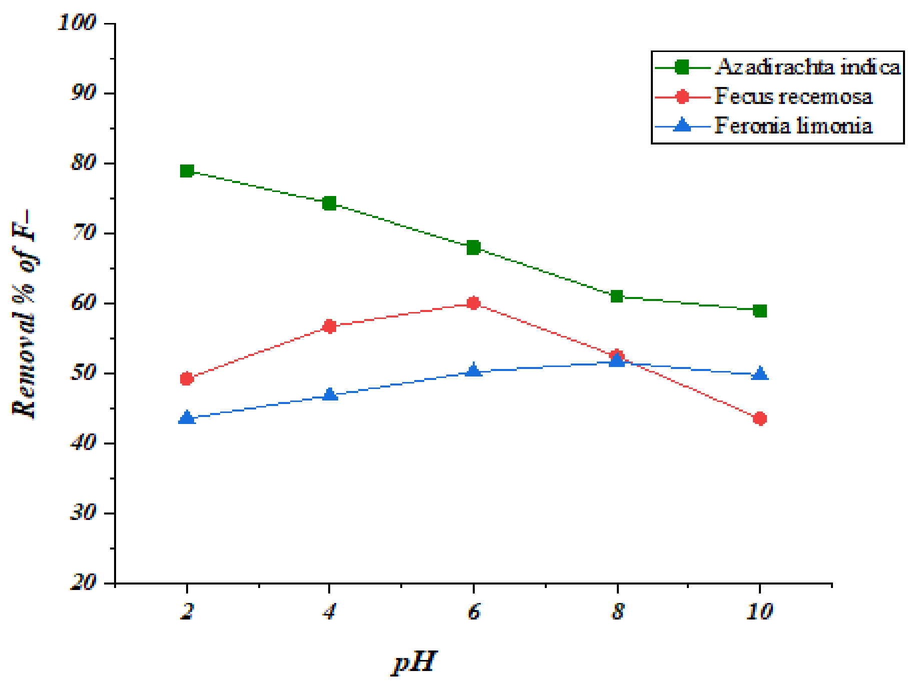


Figure 8: Removal (%) of F^- with pH

Table 5: The Efficiency of Removing F^- with pH of the Fluoridated Aqueous Solution and Different Bioadsorbents

In the pH operating order, the temperature was set to 27°C ± 0.5°C, the adsorbent dosage was 10 g/L, Ci = 10 mg/L, the contact time was 120 minutes, and the sample volume was 100 ml.								
SN	pH	Ci (mg/L)	For *Azadirachta indica*		For *Fecus recemosa*		For *Feronia limonia*	
			Ce (mg/L)	Removal % of F^-	Ce (mg/L)	Removal % of F^-	Ce (mg/L)	Removal % of F^-
1	2	10	2.10	79	4.92	49.2	5.65	43.5
2	4	10	2.57	74.3	4.33	56.7	5.32	46.8
3	6	10	3.2	68	4.0	60	4.98	50.2
4	8	10	3.9	61	4.76	52.4	4.84	51.6
5	10	10	4.1	59	5.65	43.5	5.03	49.7

(iv) Effect of Adsorbent Dosage: Fluoride removal effectiveness depends on the concentration of adsorbent dosage in a test sample. Fluoride removal rises with increasing adsorbent dosage in fluoridated water. At first, the removal of fluoride increases as the dosage increases until a very tiny change in the removal of fluoride happens, suggesting that the curve indicating that the removal remains constant at higher fluoride concentrations occurs when their maximum dose occurs. Adsorption rises, assuming fluoride adsorption is continuous at a larger dosage due to pore volume and surface saturation. A volume of 100 mL of initial fluoridated aqueous solution (10 mg/L) with a pH of 2, contact duration of 2 hours, and a temperature of 27°C 0.5°C was used. As shown in table 6 and figure 9, increasing the dose of adsorbents in fluoridated aqueous solution (adsorbate) eliminated the amount of F^- from 33.2 to 85.1% for azadirachta indica (neem), 18.7 to 52.7% for fecus recemosa (gular), and 16.2 to 48.9% for feronia limonia (kaith). It was discovered during the adsorption process that increasing the dose of adsorbents in fluoridated water enhanced adsorption effectiveness.

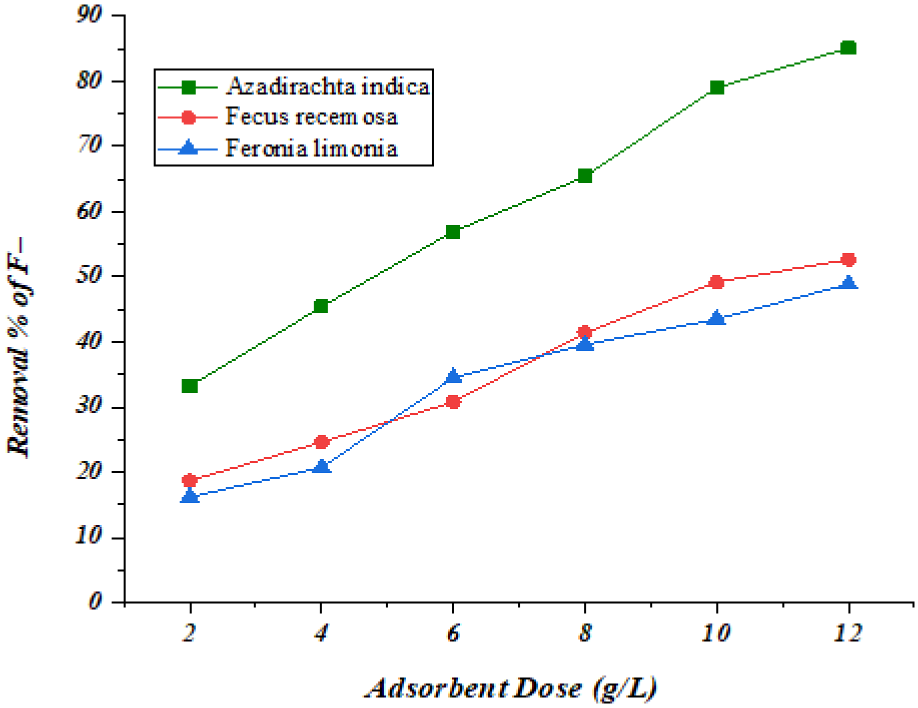


Figure 9: Removal efficiency of F^- with Adsorbent dose

Table 6: The Efficiency of Removing F^- with Adsorbent Dosage in the Fluoridated Aqueous Solution and Different Bioadsorbents

In the adsorbent dosage operating order, the temperature was set to 27°C ± 0.5°C, the, the contact time was 120 minutes, Ci = 10 mg/L, pH was 2, and the sample volume was 100 ml.								
SN	Adsorbent dose (g/L)	Ci (mg/L)	For *Azadirachta indica*		For *Fecus recemosa*		For *Feronia limonia*	
			Ce (mg/L)	Removal % of F^-	Ce (mg/L)	Removal % of F^-	Ce (mg/L)	Removal % of F^-
1	2	10	6.68	33.2	8.13	18.7	8.38	16.2
2	4	10	4.54	45.4	7.54	24.6	7.93	20.7
3	6	10	4.3	57	6.92	30.8	6.55	34.5
4	8	10	3.46	65.4	5.86	41.4	6.04	39.6
5	10	10	2.10	79	4.92	49.2	5.65	43.50
6	12	10	1.49	85.1	4.73	52.7	5.11	48.9

(v) Effect of Temperature: The sorption capabilities reached at room temperatures are dependent on hot climates for defluoridation procedures. Because of the elevated temperatures, the needs may be higher than in the field. The physical binding mechanisms of fluoride to a sorbent can be affected by temperature. Temperature, on the other hand, can directly influence the physical characteristics of a sorbent if it has been thermally treated before, causing sorption capabilities to be drastically changed. A volume of 100 mL of initial fluoridated aqueous solution (10 mg/L) with a pH of 2, contact time of 2 hours, and adsorbent dose of 2 g/L was used. As shown in table 7 and figure 10, by increasing the temperature of fluoridated aqueous solution (adsorbate), the amount of removed F^- from 69.4 to 87.2% for azadirachta indica (neem), 36.2 to 65.1% for fecus recemosa (gular), and 32 to 64.5% for feronia limonia (kaith). It was discovered during the adsorption process that increasing the temperature of adsorbate fluoridated water enhanced adsorption effectiveness.

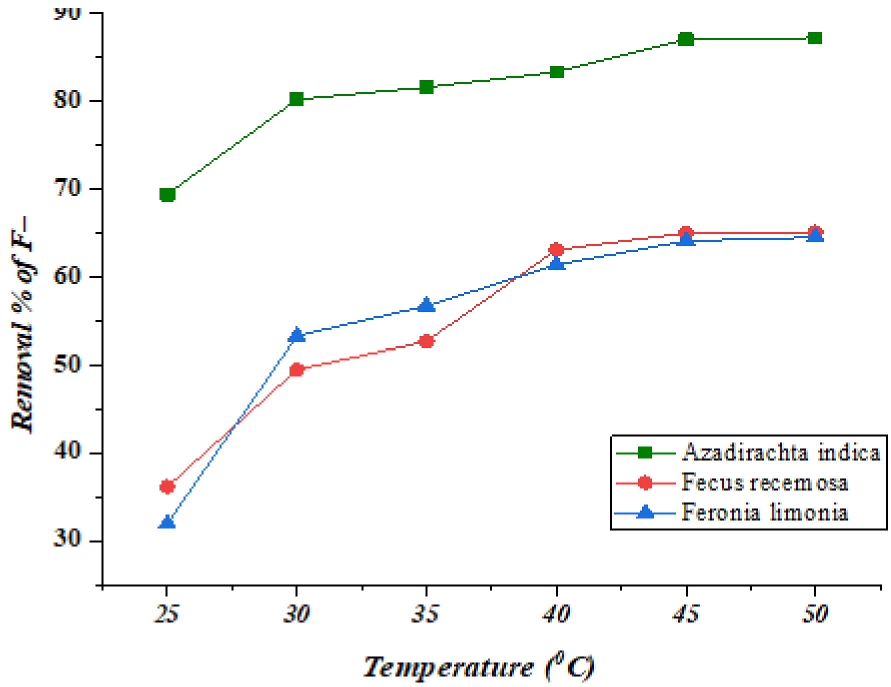


Figure 10: Removal Efficiency of F^- with Temperature

Table 7: The Efficiency of Removing F^- with Temperature in the Fluoridated Aqueous Solution and Different Bioadsorbents.

In the temperature operating order, the contact time was 120 minutes, the adsorbent dosage was 10 g/L, Ci = 10 mg/L, pH was 2, and the sample volume was 100 ml.								
SN	**Temperature (^{0}C)**	**Ci (mg/L)**	**For *Azadirachta indica***		**For *Fecus recemosa***		**For *Feronia limonia***	
			Ce (mg/L)	**Removal % of F^-**	**Ce (mg/L)**	**Removal % of F^-**	**Ce (mg/L)**	**Removal % of F^-**
1	25	10	3.06	69.4	6.38	36.2	6.8	32
2	30	10	1.98	80.2	5.05	49.5	4.67	53.3
3	35	10	1.84	81.6	4.73	52.7	4.33	56.7
4	40	10	1.67	83.3	3.87	63.1	3.86	61.4
5	45	10	1.3	87	3.5	65	3.89	64.1
6	50	10	1.28	87.2	3.49	65.1	3.55	64.5

EDX Study: The EDX analysis of a sample of neem (*Azadirachta indica*), gular (*Ficus recemosa*), and kaith (*Feronia limonia)* leaves powder after and before treatment with fluoride water is included as a figure from 11 to 16.

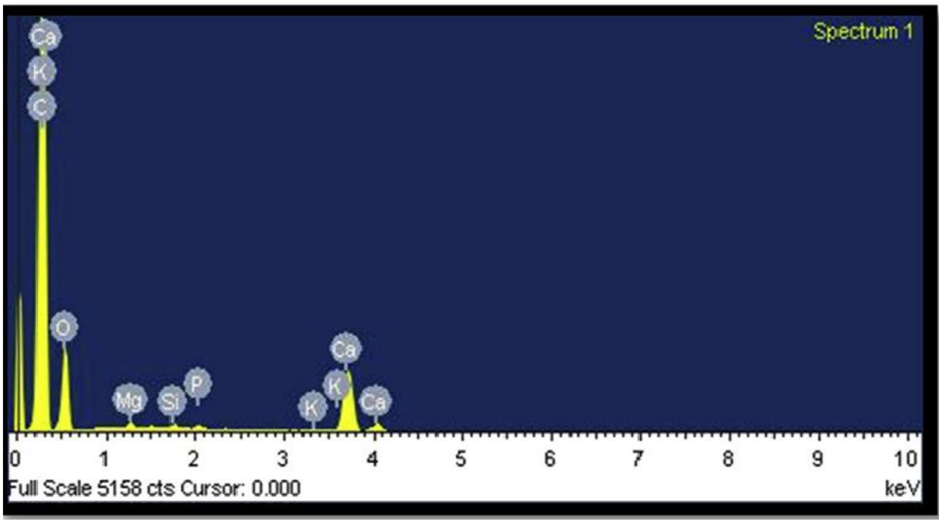


Figure 11: EDX Monograph of before Fluoride Adsorption for Neem (*Azadirachta Indica*) Leaves Powder

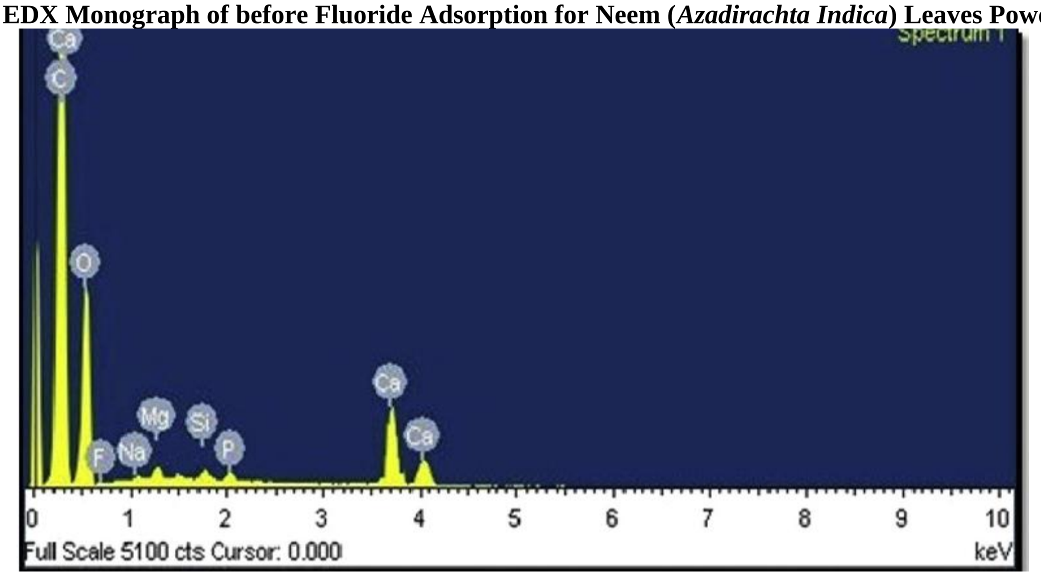


Figure 12: EDX Monograph of after Fluoride Adsorption for Neem (*Azadirachta Indica*) Leaves Powder

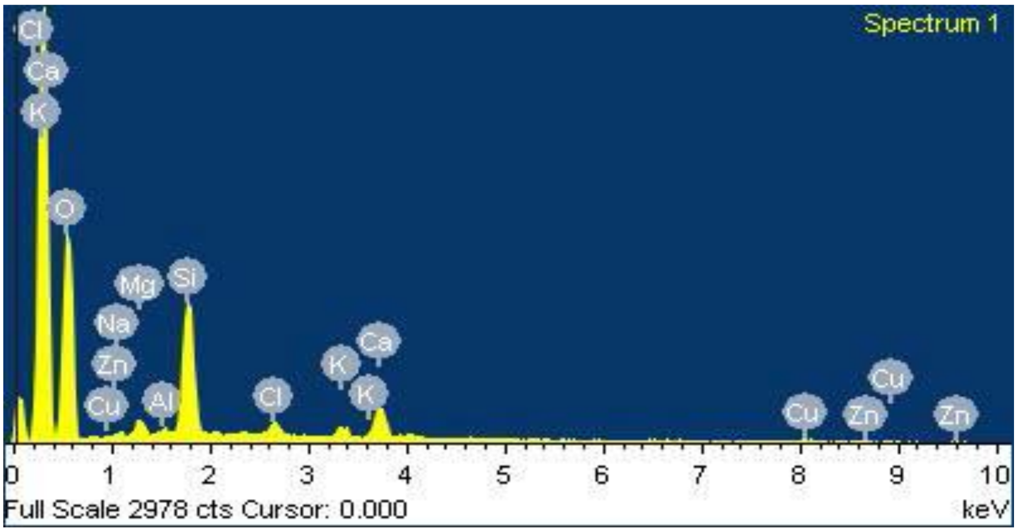


Figure 13: EDX Monograph of before Fluoride Adsorption for Gular (*Ficus Recemosa*) Leaves Powder

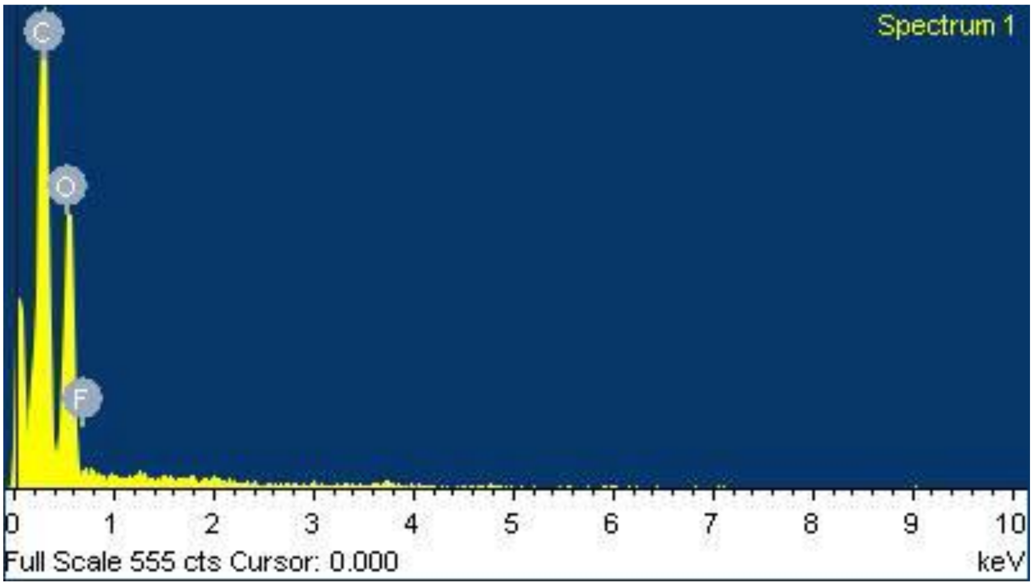


Figure 14: EDX Monograph of after Fluoride Adsorption for Gular (*Ficus Recemosa*) Leaves Powder

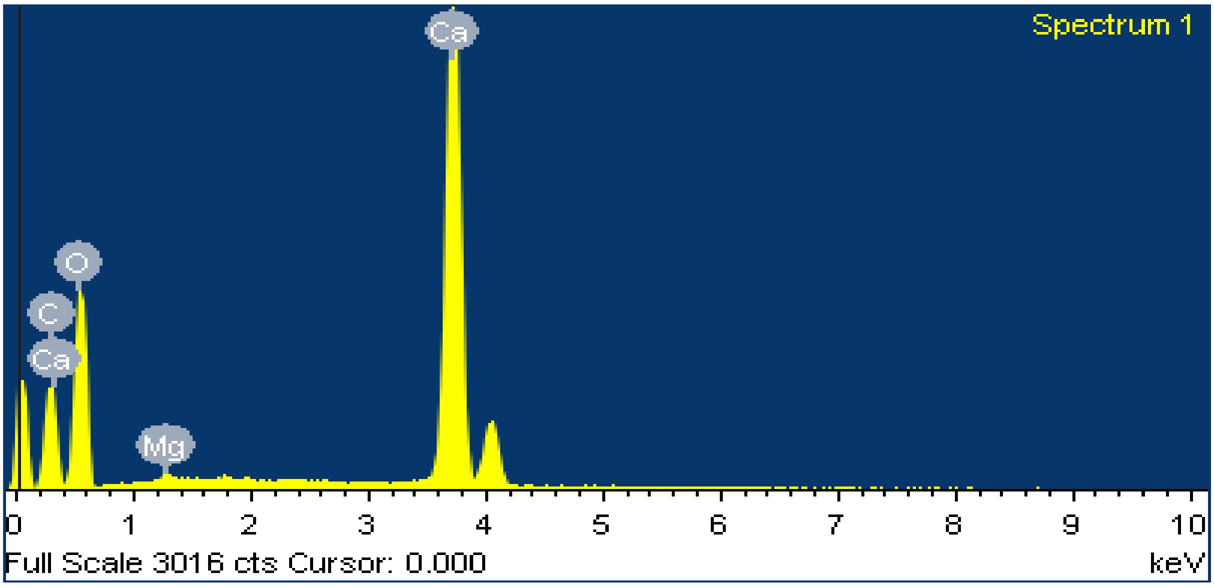


Figure 15: EDX Monograph of before Fluoride Adsorption for Kaith (*Feronia Limonia)* Leaves Powder

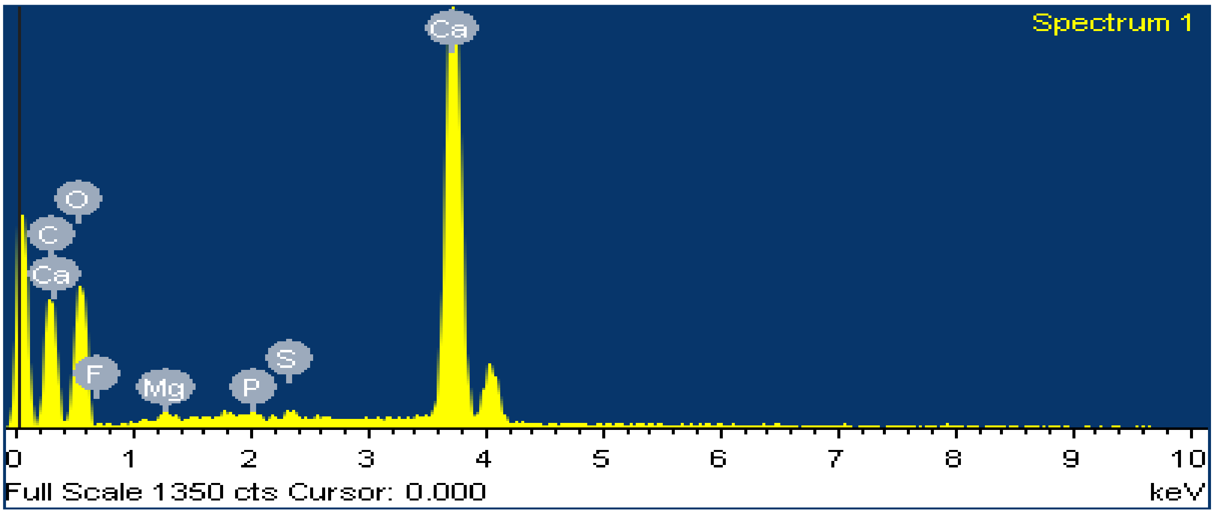
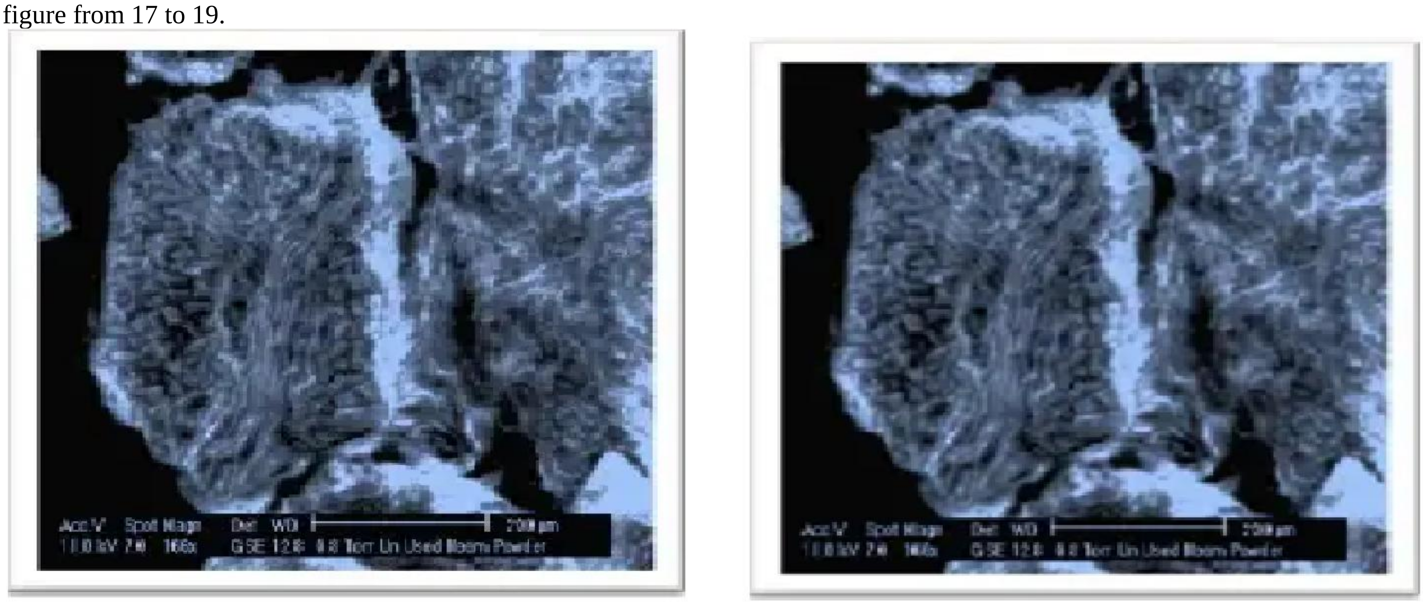


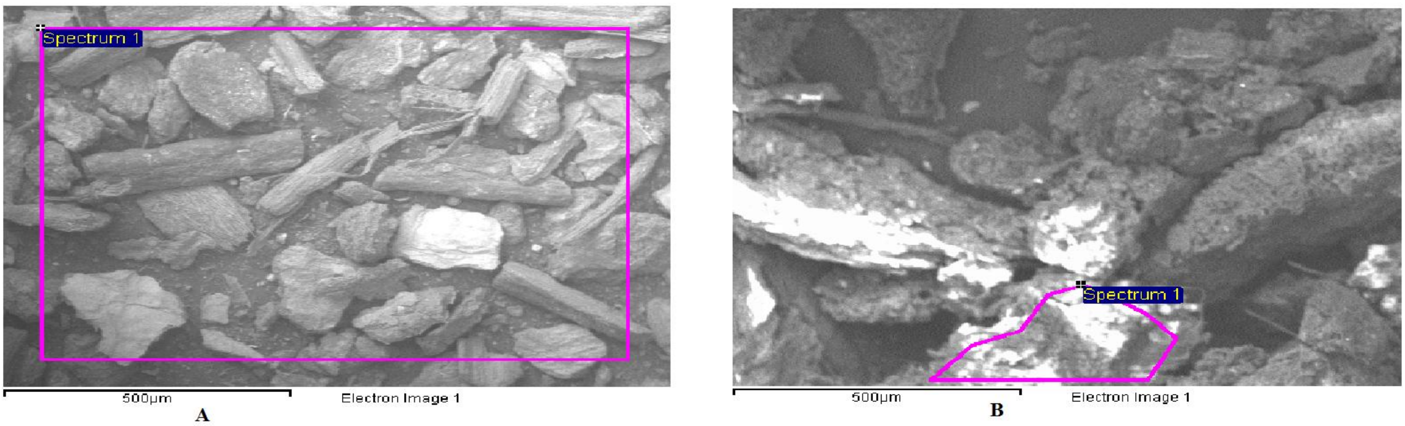
Figure 16: EDX Monograph of after Fluoride Adsorption for Kaith (*Feronia Limonia)* Leaves Powder

SEM Study: The scanning electron microscopic analysis of a sample of neem (*Azadirachta indica*), gular (*Ficus recemosa*), and kaith (*Feronia limonia)* leaves powder after and before treatment with fluoride water is included as a figure from 17 to 19.



A **B**

Figure 17: SEM Image of Neem (*Azadirachta Indica*) Leaves Powder (A) = before and (B) = after Fluoride Removal from Water



A **B**

Figure 18: SEM Image of Gular (*Ficus recemosa*) leaves powder (A) = before and (B) = after Fluoride Removal from Water

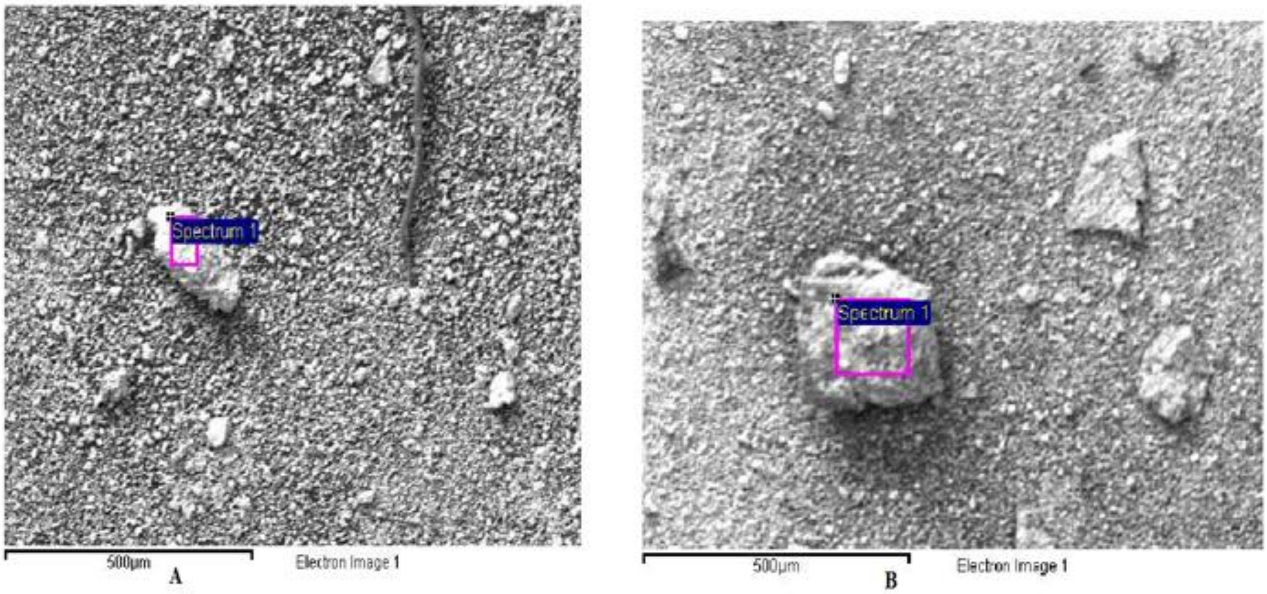


Figure 19: SEM Image of Kaith (*Feronia Limonia*) Leaves Powder (A) = before and (B) = after Fluoride Removal from Water

4. CONCLUSION

Fluorosis is a major public health issue in India. This method helps eliminate fluoride from water. Examining the numerous low-cost adsorbents offered here includes a significant capacity to eliminate fluoride. Inexpensive and effective adsorbents can be used instead of commercially available adsorbents. More research is required to appreciate the mechanism of low-cost adsorption better and adequately reveal the technology. We will also create bio-adsorption/waste material nano-particles during the bioadsorption process for the defluoridation of drinking water. This study discussed the removal of fluoride from water using bioadsorbents. Neem (Azadirachta indica), Gular (Ficus recemosa), and Kaith (Feronia limonia) leaves powder were used for the removal of fluoride in water. The bioadsorbents used to remove fluoride in the study proved very effective.

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