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Removal of Fluoride from water using Pumice Stone as an Adsorbent

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ABSTRACT: In this paper, removal of fluoride from water using crushed pumice stone adsorbent is presented. The size of crushed pumice stone was sieved through IS sieve size of 0.6-1.18 mm followed by aluminium oxide coating. The experiment was performed in batch study followed by column bed filter. In batch analysis, equilibrium time, optimum dose and pH variation of adsorbent were performed. It was observed that at the dose of 40g/L of adsorbent and pH of 7.2 about 93% of fluoride was removed in 4 hours from contaminated water having initial concentration of 5ppm. Adsorption isotherm follows Freundlich isotherm. The column bed filter was effective in defluoridation of water under continuous flow condition and may be used for full scale water treatment plant. The breakthrough time t_b was observed to be about 36 hrs, means column filter worked efficiently upto about 36 hrs.

KEYWORDS: Pumice stone, Freundlich isotherm, aluminium oxide coating

I. INTRODUCTION

Drinking water quality and accessibility are significant issues around the globe. Health risks may emerge from consumption of infectious agent contaminated water, toxic chemicals, and radiological hazards.

Important progress has been made on the implementation of the global goal for safe drinking water in 2010 well in advance of the MDG 2015 dead line (UNICEF and WHO, 2015) in the Millennium Development Objective (MDG) period (1990–2015). Despite its progress and the fact that 91% of the world's population now has access to safe drinking water, it has also been seen that some developing and less developed countries, including South and Central Asia, North Africa, have not achieved the objective of the safe drinking water. Furthermore, enormous disparities have also been observed in the world's access to safe drinking water. These include inequalities such as the urban and rural population gap, the water collection gender burden, and the gap between the wealthy, poorest, and most valued sectors of society that lack

access to enhanced water facilities. Eight out of 10 individuals were found in rural regions who are still unable to access secure drinking water sources (UNICEF and WHO 2015).

Fluoride is toxic inorganic monoatomic anion with rating higher than lead in affecting groundwater contaminants. It is one of the most bone seeking elements of human beings. Water fluoridation is an efficient measure of public health to prevent tooth decay in kids and adults; it has particular impact in communities with moderate to elevated danger of decay of the tooth. It can help improve general health and decrease disparities in communities bad oral health levels.

In India alone, endemic fluorosis is estimated to affect around one million people and is a major problem in 22 of the 29 states, especially this problem is common in countries such as Andhra Pradesh, Karnataka Kerala, Rajasthan, Gujarat, Uttar Pradesh, Punjab, Orissa and Jammu and Kashmir, Bihar, UP, West Bengal. The concentration of fluoride in drinking water should vary slightly more and less than 1 mg / L, according to the WHO. Fluoride levels up to 1.5 mg / L can be received in areas with low water intake such as temperate regions. The Bureau of Indian Standards BIS (IS-10500) has provided permissible and desirable fluoride limits in drinking water of 1.0 and 1.5 mg / L respectively.(Vardhan and Karthikeyan 2011)[17].

According to one study, 30- 50% of districts of Bihar are affected by fluorosis. According to government of Bihar 8,188 villages in 11 districts have high fluoride concentration in groundwater. (Gouri and Choudhary 2017) [5].

These challenges have been eliminated by finding cost-effective fluoride removal technologies for rural areas in developing countries, and undeveloped countries. Adsorbents are available in almost all local areas of India. (Yadav et

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al. 2013) [22]. With this view, current work is being taken to study the feasibility of removing fluoride from an aqueous solution that overcomes it with aluminum oxide coated pumice(AOCP).

Table 1: Fluoride conc. and health effects (Salifu n.d.)[12]

S.no.	Fluoride conc.(mg/L)	Health Effects
1	<0.5	Dental caries
2	0.5-1.5	Promotes dental health/good bone development
3	1.5-4	Dental fluorosis
4	>4	Dental / skeletal fluorosis
5	>10	Crippling fluorosis
6	>50	Thyroid changes
7	>100	Growth retardation
8	>120	Effects on kidney
9	About 50-250	Death

II. MATERIALS AND METHODS

A. Reagents and Equipments

A.1 Chemicals

All chemicals used are analytical grade. The chemicals used are – Aluminium sulfate $[Al_2(SO_4)_3]$, sodium hydroxide [NaOH], aluminium hydroxide $[Al(OH)_3]$, ammonium hydroxide $[NH_4OH]$, sodium fluoride[NaF], hydrochloric acid, nitric acid, sodium carbonate & TISAB solution.

A.2 Water

Distilled water was used for washing pumice stone which is preparation of adsorbent. Milli-Q water was used in preparation of stock solution which is used by ion selective electrode.

A.3 Adsorbent

The adsorbent is prepared from locally available material pumice stone which is crushed and sieved and by employing chemical treatment process used as adsorbent for fluoride removal.

A.4 Equipment

Various type of equipment which are listed below were used for determining different parameter and carrying out various tests-

Impact testing machine, IS sieve of sizes 0.6-1.18mm, Whatman No-42 filter paper, Buchner funnel and vacuum pump, Thermo selective ion selective fluoride electrode, Incubator shaker, pH meter, Analytical balance, Borosilicate burette glass

A.5 Glassware

All glassware were cleaned using nitric acid and washed with distilled water. They were then dried properly before use. The glassware used are-

Volumetric flask of 10ml, 50ml, 100ml, 250ml, 500ml, 1000ml. Conical flask of 250ml, pipettes of measuring capacity of 1ml, 5ml, 10ml, beakers of 25ml, 100ml, 250ml, 500ml, 1000ml, Erlenmeyer flask, funnel, stirrer, burette, glass bottles of 300ml, plastic bottle of capacity 1000ml.

A.6 Miscellaneous

Air tight container, hand gloves, tissue paper.

B. Preparation of materials

B.1 Preparation of chemical reagent

All the chemical reagents were prepared as per standard methods for the examination of water and waste water. Stock fluoride solution: 221 mg anhydrous sodium fluoride was dissolved in distilled water and diluted to 1000ml. It will give 100mg/L fluoride concentration. Fluoride concentration required for test will be prepared from stock solution. 5ml of stock fluoride solution was diluted to 1000ml distilled water to obtain 5 mg/L fluoride concentration.

B.2 pH adjustment

Preparation of 1M NaOH solution- Dissolve 2g NaOH pellets in 50ml distilled water.

Preparation of 1M HNO₃ solution- Dissolve 3.4ml HNO₃ in 50ml distilled water.

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B.3 Preparation of chemical for calibration

From standard fluoride solution having 100ppm concentration 10 ml is diluted to 100 ml distilled water to obtain 10ppm fluoride concentration.

1ml of standard fluoride solution is diluted to 100ml distilled water to obtain 1ppm fluoride concentration. This solution is used for calibrating ion selective electrode.

B.4 Preparation of Adsorbent

Synthesis of AOCP

Pumice stone is crushed with impact testing machine and sieved to a size of 0.6-1.18mm IS sieve, then it is washed with distilled water and air dried. Adequate amount of $0.5M \text{ Al}_2(\text{SO}_4)_3$ is added to fully soak about 25g of dried pumice in vessel. Mix is agitated for 1.5 hours at 150rpm and then pumice is removed and air dried at room temperature. To neutralize it and complete the coating process, dried pumice is soaked in 3 M NH₄OH. Coated sample is now sieved and washed with distilled water at pH-7±0.1 to remove free Al₂O₃.

$\rightarrow Al_2(SO_4)_3 + NH_4OH (NH_4)_2SO_4 + Al(OH)_3$

Aluminium oxide coated pumice(AOCP) is lastly dried and stored for fluoride adsorption.



Fig. 1: Flowchart of DE-fluoridation process by AOCP

C. Experimental Studies

C.1 Batch Study

Kinetic experiments are performed using a constant AOCP and uncoated pumice dose of 10 g/L and aqueous samples are taken at pre-determined times. The adsorption experiments are conducted at a neutral pH 7.0 \pm 0.1 and room temperature (30°C), using 25ml of model water in 250 ml conical flask bottles and adding 0.25g of adsorbent. The time at which the fluoride concentration of the solution ceased to change was taken as the equilibrium time. The effect of pH on stock fluoride solution of known concentration of 5ppm for an adsorbent dose of 10gm/L and contact time of 4 hours was observed by varying pH 1 to 11. Dose varying from 0.05mg/L to 2.5mg/L at pH 7 and room temperature was observed. The residual fluoride concentration in the filtrate is determined potentiometrically using an Ion-selective electrode. The total ionic strength adjusting buffer (TISAB) is used to release any complexed fluoride ions before total fluoride measurements.

C.1.1 Adsorption Kinetics

The adsorption data were fitted to kinetic models, namely the pseudo-first order model, pseudo-second order model and intra-particle diffusion model. The kinetic data were correlated with the linear forms of these models (Sivarajasekar et al. n.d.)[15].

The pseudo-first and second order kinetic models (Eq. 1,2) assume that the adsorption is a pseudo chemical reaction, and the adsorption rate could be determined, respectively, by the first order and second order rate constants (Mondal et al. 2012)[7].

The linearised form of pseudo-first order rate equation is given as

$$\log(q_e - q_t) = \log(q_e) - \left(\frac{K_1}{2.303}\right) t (1)$$

where, q_e and q_t are the amount of fluoride adsorbed (mg/g) at equilibrium and at any time, t (hrs) respectively. K_1 is the first order adsorption rate constant.

The pseudo-second-order adsorption kinetic model is as follows:

Volume 10, Issue 9, September 2021

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(2)

$$\frac{t}{q_t} = \frac{1}{K_2 q_e^2} + \frac{1}{q_e} t$$

where, K_2 is the second order adsorption rate constant

The value of adsorption rate constant K_2 and q_e are obtained by plotting t/q_t versus t (hrs).

Intra-particle diffusion model created by Weber & Morris in 1963 was tested to identify the adsorption mechanism of fluoride and used to determine the rate limiting step. (Desta Gebrewold et al. 2018)[3].

$$q_t = K_d t^{\frac{1}{2}} + C$$
(3)

where, $K_d(\text{mg/g h}^{1/2})$ represents the intra particle diffusion rate constant, which represents the fraction of fluoride removal, t represents the contact time (hours), and C (mg / g) is the intercept, which gives the concept of boundary layer thickness.

C.1.2 Adsorption isotherm model

The experimental equilibrium data were fitted to isotherm models to model fluoride adsorption on AOCP; i.e. Freundlich and Langmuir Equations to find the best suited model for experimental data.

The Langmuir adsorption isotherm model is expressed as (Eq. 4)

$$\frac{C_e}{q_e} = \frac{1}{k_a Q_m} + \frac{C_e}{Q_m} \tag{4}$$

where, C_e is the equilibrium concentration (mg/L), q_e is the amount of solute adsorbed per unit of adsorbent at equilibrium(mg/g). Q_m and k_a are the monolayer adsorption capacity (mg/g) and energy of adsorption respectively.

Freundlich isotherm model (Sivasankaret al. 2013), suggests that adsorption process takes place on a heterogeneous surface and can be expressed as Eq. (5):

$$\log(q_e) = \frac{1}{n} \log(C_e) + \log(k_f) \tag{5}$$

where, k_f and 1/n are empirical constants related to binding energy or as an indicator of adsorption capacity and measure of intensity of adsorption respectively. The value of *n* from 1 to 10, shows positive adsorption situation (Huang et al. 2012)and small value of *n* shows a weak bond between adsorbate and adsorbent (Jamode et al. 2004). The lower value for k_f shows a small rate of removal of adsorbents (Rao et al. 2009). Higher the maximum adsorption capacity, higher the k_f and also higher the 1/n value, more favorable is the adsorption.

C.2 Column Study

The column study consists of investigating the suitability of the AOCP in laboratory column experiments under continuous flow conditions.

Fixed parameters for fluoride removal using AOCP in column filter are

Bed depth- 11 cm, Flow rate Q- 20ml/hr, Volume of AOCP- 10cm³, Initial fluoride conc. in water- 5±0.1ppm, pH of influent and effluent water- 7.7, Temp.- Room temperature

Breakthrough curves, and Thomas and Adams-Bohart model were analysed.

C.2.1 Modeling of Breakthrough Profiles

Breakthrough curve is ratio of effluent-to-influential fluoride concentration (Ct / Co) to time depicting the fluoride ion loading behavior from solution to AOCP column filter. At an effluent fluoride concentration of 1.5 mg/L [WHO guideline] breakthrough was obtained. This gives Ct/Co value of 0.3. The breakthrough time (t_b) is when effluent concentration reaches 30% of influent concentration.

The fluoride adsorption capacity of AOCP at breakthrough (q_b) (mg/g) for a given bed depth is given by

$$q_b = \frac{Q_b t_b C_o}{M} \tag{6}$$

where M is mass of adsorbent for given bed depth.

Design of fixed-bed treatment plants by the use of breakthrough curve models is useful to predict the effects of the various operating parameters (e.g. flow rate, influential adsorbate concentration) on a breakthrough profile in order to determine the optimum operational conditions. The column experimental data were fitted to two commonly used mathematical models namely, Thomas model and Adams-Bohart model to study dynamic behavior of fluoride adsorption in AOCP fixed bed column filter.



Volume 10, Issue 9, September 2021

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C.2.2 Thomas Model

Thomas derivation assumes:

- Langmuir kinetics of adsorption-desorption, and
- Second order reversible reaction kinetics without any internal-external diffusion limitations.

It shows plug flow behavior of fixed bed. Using the kinetic model created by Thomas, the data obtained from continuous flow studies were used to calculate the maximum solid phase fluoride concentration on adsorbent and the adsorption rate constant.

The Thomas model's non-linear and linear expressions are described respectively as equations (7) and (8):

$$\frac{C_{t}}{C_{o}} = \frac{1}{1 + \exp\left(\frac{K_{TH}q_{TH}M}{Q} - K_{TH}C_{o}t\right)}$$
(7)
$$\ln\left(\frac{C_{o}}{C_{t}} - 1\right) = \frac{K_{TH}q_{TH}M}{Q} - K_{TH}C_{o}t$$
(8)

where, K_{TH} (L/h mg) is Thomas rate constant, q_{TH} (mg/g) is maximum equilibrium adsorption capacity, M (g) is quantity of adsorbent, Co (mg/L) is influent concentration, Ct (mg/L) is effluent concentration, t (h) is time, Q (L/h) is flow rate.

C.2.3 Adams-Bohart Model

This model is based on surface reaction theory. It predicts that equilibrium is not instantaneous; so rate of adsorption is proportional to both remaining capacity of adsorbent and conc. of adsorbate. It assumes that rate of adsorption is limited by external (film) mass transfer. The non linear and linear form of this model is given as equation:

$$\frac{C_t}{C_o} = \exp\left(K_{AB}C_O t - K_{AB}N_O\frac{Z}{V}\right)$$
(9)
$$\ln\left(\frac{C_t}{C_o}\right) = K_{AB}C_O t - K_{AB}N_O\frac{Z}{V}$$
(10)

where, $K_{AB}(L/mg h)$ is Adams-Bohart rate constant, No(mg/L) is saturation concentration, Z(m) is column bed depth, V(m/h) is linear velocity of influent solution, Co(mg/L) is influent concentration, Ct(mg/L) is effluent concentration, t (h) is time. The linear flow rate V is given by V=Q/A where Q (L/h) is flow rate of model water tank, and A (m²) is cross sectional area of bed, i.e. burette.

III. RESULTS AND DISCUSSION

D.Batch study

D.1 Equilibrium time of adsorbents

Uncoated pumice stone

The stock solution of fluoride having concentration 5 mg/L and volume 25mL was taken in conical flask and kept in incubator to ensure continuous mixing of adsorbent with solution. It was subjected to 10gm/L of adsorbent dose and at a regular interval 15 min, the solution was taken out and tested for remaining fluoride concentration. The samplings were taken upto 2 hrs.From the graph it is found that with increasing time fluoride removal increases and about 2 hrs equilibrium is reached but removal efficiency is only 50% with final fluoride conc. of about 2.5ppm. As final fluoride conc. is not within the permissible limit so it is discarded as an adsorbent. Equilibrium time of uncoated pumice stone are given below



Volume 10, Issue 9, September 2021

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Fig. 2: Effect of Time on UP

Aluminium oxide coated pumice stone (AOCP)

The sampling was taken upto 24 hrs.From the graph it is found that with increasing time fluoride removal increases and about 4 hrs equilibrium is reached. Permissible fluoride conc. of 1.5 mg/l was obtained in about 1 hour. Removal efficiency is 90% with final fluoride conc. of 0.42 ppm. Equilibrium time of AOCP are given below



Fig. 3: Effect of Time on AOCP

D.2 Effect of pH

pH was varied from 1-11. Fluoride adsorption was maximum in acidic range and as pH increases adsorption decreases and becomes nearly constant at pH of 11. At pH of 1 removal efficiency was 99% but fluoride conc. was 0.0005ppm which was not within permissible limit. Adsorption of fluoride within pH range of 6-8 showed good results as per WHO recommendation with fluoride removal of 90%. Variation of pH on percentage adsorption is shown below



Fig. 4: Effect of pH on fluoride removal

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D.3 Effect of dose

For a fluoride conc. of 5mg/L, using different doses of adsorbent (2-100gm/L) fluoride removal was observed. Test was performed for a contact time of 4 hrs and pH 7. It was observed that fluoride removal efficiency was increased from 24% to 96% when AOCP dose increased from 2 to 100mg/L. It is due to increased availability of active sites for fluoride ions as dose increases. However removal efficiency was negligible after a dose of 100gm/L which is considered as optimum dose. Variation of adsorption efficiency and adsorbent dose is shown below



Fig. 5: Effect of dose on fluoride removal

D.4 Adsorption Kinetics of AOCP

Kinetics of AOCP adsorbent follows Pseudo second order kinetics. It is shown form result pseudo second order is better than pseudo first order model.



Fig. 6: Pseudo First Order Kinetic Model



Fig.7: Pseudo Second Order Kinetic Model



Volume 10, Issue 9, September 2021

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Fig. 8: Intra-Particle Diffusion Model

Table 2: Kinetic models and rate parameters

Adsorption Kinetics	Equation	\mathbb{R}^2
Pseudo first order	y = -0.1079x -	0.7455
	1.2583	
Pseudo second	y = 2.1716x + 0.292	1
order		
Intra particle	y = 23.477x - 7.938	0.6448
diffusion		

D.5 Adsorption Isotherms of AOCP

For AOCP adsorbent different isotherm was study, such as Freundlich and Langmuir Isotherm. The coefficient of determination (R^2) values show that the best fit isotherm model is Freundlich Isotherm with R^2 value of 0.9015. The various isotherms are shown below



Fig. 9: Freundlich Isotherm for AOCP

Table 3: Freundlich isotherm parameters

Isotherm parameter	Isotherm value	
K_{f} (mg/g)	0.228	
n	1.278	
\mathbb{R}^2	0.901	



Volume 10, Issue 9, September 2021

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Fig, 10: Langmuir Isotherm for AOCP

 Table 4: Langmuir isotherm parameters

Isotherm parameter	Isotherm value
$q_m (mg/g)$	0.762
k _a (L/mg)	0.4748
R^2	0.700

E. Column Study

Fluoride concentration is varying with respect to time as shown below



Fig. 11: Variation of fluoride concentration with time

E.1 Breakthrough curves for fluoride adsorption onto AOCP

It is observed that the curve follows the characteristic S shape. The breakthrough time t_b was observed to be about 36 hrs, means column filter worked efficiently upto about 36 hrs. The curve is shown below



Fig. 12: Breakthrough curve

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E.2 Modeling of breakthrough profiles

The coefficient of determination R^2 shows that Adams Bohart model best describes the fluoride adsorption under continuous flow conditions in AOCP column filter. The variation of various model is given below

Thomas model



Fig. 13: Thomas model for fluoride adsorption on AOCP

Table 5: Thomas model parameters

Bed depth	Thomas Model		
	K _{th} (L/h/mg)	$Q_{th} (mg/g)$	\mathbb{R}^2
0.11m	0.019	0.5263	0.726

Adams Bohart model





 Table 6: Adams Bohart model parameters

Bed depth	Adams-Bohart model		
	K _{AB} (L/h/mg)	$N_o (mg/L)$	\mathbb{R}^2
0.11m	0.011	280.72	0.788

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IV. CONCLUSION

It was found that the modification of pumice particles by alumina coating is effective for fluoride adsorption. It is also seen that uncoated pumice stone though it removes fluoride to some extent yet it does not reduces final conc. to WHO drinking water standards. The equilibrium time for AOCP was approximately 4 hrs with 89.2% fluoride removal from 5ppm to 0.54ppm. The change in pH of the AOCP indicates that it works best in the pH range of 6 to 9 and is suitable for removing fluoride from groundwater and tube-wells in rural areas. At a dose of about 40gm/L about 93% fluoride is removed and with further increase in dose there is negligible variation in fluoride removal. The batch adsorption kinetics show that it follows pseudo second order reaction ($R^2=1$) means adsorption is chemisorption. AOCP adsorbent follows Freundlich Isotherm with $R^2=0.9015$ means it is monolayer chemisorption.

AOCP fixed column bed filter was effective in DE-fluoridation of water under continuous flow condition and may be used for full scale water treatment plant. The breakthrough curve was observed to follow characteristics S shape curve. The advance was reached when the fluoride effluent conc. reached 1.5 mg / L, the WHO reference value. This corresponds to the Ct / Co value of 0.3. The breakthrough time t_b was observed to be about 36 hrs, means column filter worked efficiently upto about 36 hrs. The fluoride adsorption of AOCP exhausted after about 50 hrs. The coefficient of determination R² shows that Adams Bohart model best describes the fluoride adsorption under continuous flow conditions in AOCP column filter.

Thus in developing country like India, AOCP could be a possible adsorbent for fluoride removal where indigenous material could be a cost reduction factor and may be easily available in rural areas in household levels for water DE-fluoridation.

REFERENCES

- Chaudhary, Mohit, and Abhijit Maiti. 2019. "Defluoridation by Highly Efficient Calcium Hydroxide Nanorods from Synthetic and Industrial Wastewater." *Colloids and Surfaces A* 561(October 2018): 79–88. https://doi.org/10.1016/j.colsurfa.2018.10.052.
- [2] College, Kakatiya Government. 2014. "Suitable Methods for Purification of Fluoride Free Water." (5): 38-42.
- [3] Desta Gebrewold, Berhane et al. 2018. "Fluoride Removal from Groundwater Using Chemically Modified Rice Husk and Corn Cob Activated Carbon."
- [4] Ganvir, Vivek, and Kalyan Das. 2011. "Removal of Fluoride from Drinking Water Using Aluminum Hydroxide Coated Rice Husk Ash." *Journal of Hazardous Materials* 185(2–3): 1287–94.
- [5] Gouri, Kumari, and Sunil K. Choudhary. 2017. "Fluoride Contamination in Groundwater Sources of Bhagalpur Municipal Corporation Area, Bhagalpur, Bihar." *IOSR Journal of Environmental Science, Toxicology and Food Technology* 11(01): 45–49.
- [6] Meenakshi, and R. C. Maheshwari. 2006. "Fluoride in Drinking Water and Its Removal." *Journal of Hazardous Materials* 137(1): 456–63.
- [7] Mondal, Naba Kr et al. 2012. "A Comparative Study on the Batch Performance of Fluoride Adsorption by Activated Silica Gel and Activated Rice Husk Ash." *Agris On-line Papers in Economics and Informatics* 2(3): 1643–61.
- [8] Oladoja, N A et al. 2019. "Defluoridation Efficiency of a Green Composite Reactive Material Derived from Lateritic Soil and Gastropod Shell." *Sustainable Chemistry and Pharmacy* 12(August 2018): 100131. https://doi.org/10.1016/j.scp.2019.100131.
- [9] Oladoja, N A, Y Liu, J E Drewes, and B Helmreich. 2016. "Preparation and Characterization of a Reactive Filter for Groundwater Defluoridation." CHEMICAL ENGINEERING JOURNAL 283: 1154–67. http://dx.doi.org/10.1016/j.cej.2015.08.059.
- [10] Rajkumar, S. et al. 2015. "Low-Cost Fluoride Adsorbents Prepared from a Renewable Biowaste: Syntheses, Characterization and Modeling Studies." *Arabian Journal of Chemistry*.
- [11] Razbe, Neelo, Rajesh Kumar, Pratima, and Rajat Kumar. 2013. "Various Options for Removal of Fluoride from Drinking Water." *IOSR Journal of Applied Physics (IOSR-JAP)* 3(2): 40–47.
- [12] Salifu, Abdulai. Fluoride Removal from Groundwater by Adsorption Technology.
- [13] Saxena, K L, and R Sewak. 2015. "Fluoride Consumption in Endemic Villages of India and Its Remedial Measures." 4(1): 58–73.
- [14] Shen, Feng, Xueming Chen, Ping Gao, and Guohua Chen. 2003. "Electrochemical Removal of Fluoride Ions from Industrial Wastewater." *Chemical Engineering Science* 58(3–6): 987–93.
- [15] Sivarajasekar, N et al. "Defluoridation of Water Using Adsorbents A Concise Review."

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- [16] Thole, Bernard. 2013. "Ground Water Contamination with Fluoride and Potential Fluoride Removal Technologies for East and Southern Africa." *Perspectives in Water Pollution*.
- [17] Vardhan, C M Vivek, and J Karthikeyan. 2011. "Low-Cost Materials." : 1–14.
- [18] Vardhan, C M Vivek, and M Srimurali. 2018. "Journal of Environmental Chemical Engineering Preparation of Lanthanum Impregnated Pumice for de Fl Uoridation of Water : Batch and Column Experiments." 6(November 2017): 858–65.
- [19] Waghmare, Sanghratna S, and Tanvir Arfin. 2015. "Fluoride Removal from Water by Various Techniques: Review." 2(9): 560–71.
- [20] Xia, Yan et al. 2019. "Facile de Fl Uoridation of Drinking Water by Forming Shell @ Fl Uorapatite Nanoarray during Boiling Egg Shell." *Journal of Hazardous Materials* 361(September 2018): 321–28. https://doi.org/10.1016/j.jhazmat.2018.09.007.





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