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Retraction

Retracted: Investigation on Efficient Removal of Fluoride from Ground Water Using Activated Carbon Adsorbents

Adsorption Science and Technology

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope

(2) Discrepancies in the description of the research reported

(3) Discrepancies between the availability of data and the research described

(4) Inappropriate citations

(5) Incoherent, meaningless and/or irrelevant content included in the article

(6) Manipulated or compromised peer review

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

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[1] N. D. K. R. Chukka, P. Gomathi Nagajothi, L. Natrayan et al., "Investigation on Efficient Removal of Fluoride from Ground Water Using Activated Carbon Adsorbents," *Adsorption Science & Technology*, vol. 2022, Article ID 7948069, 9 pages, 2022.

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Research Article

Investigation on Efficient Removal of Fluoride from Ground Water Using Activated Carbon Adsorbents

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Groundwater seems to be the most significant natural source of potable water for millions of individuals. Fluoride pollution in groundwater is a big problem in Tamil Nadu's Dharmapuri area. According to a survey done in a school in the Dharmapuri area, dental and skeletal fluoroses afflict almost 75% of school kids. There is no proven or recommended cost-effective strategy for lowering fluoride levels in the home. This study proposes cost-effective and efficient natural treatment approaches for lowering fluoride levels. In this experiment, fluorides in groundwater are eliminated to a suitable extent utilizing natural adsorbents. Neem stem charcoal (activated carbon), neem leaves powder, dry coconut husk, coconut shell charcoal (activated carbon), and rice husk powder are natural adsorbents. The adsorbents were utilized at different concentrations until the best concentration was found. The ideal concentration removes the bulk of fluoride from groundwater and delivers adequate treatment. People could adopt this cost-effective procedure because just a few components are enough. As per the Bureau of Indian Standards, the concentration should not exceed 1.5 ppm, and it should not be lesser than 1 ppm; keeping this in mind, the neem stem charcoal which has higher efficiency in removing fluoride can be used in extensive environments, but in this selected place, it reduces the concentration even below 1 ppm, which relays below the standard level. As a result, adopting these procedures helps prevent dental and skeletal fluoroses, which is common among young people.

1. Introduction

Most people depend on groundwater for drinking and domestic purposes. In the last few decades, we observed that groundwater has been polluted by human activities in many countries, causing groundwater contamination [1]. There are fewer effective methods, and they cannot be accessible for individual dwellers to treat the excessive fluoride and other heavy metals available in groundwater [2]. This study ensures an economical and efficient method of removing the contamination as we are aware of fluoride, which plays a vital role in contamination and produces health issues in humans. The

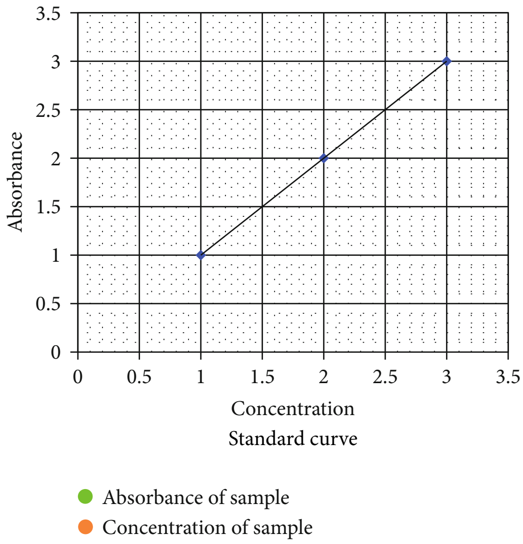

Figure 1: Curve of the concentration and absorbance.

important reason for contamination of fluoride in groundwater is geological and anthropogenic activities. World Health Organization (WHO) has provided some guidelines for safe drinking water [3] with some permissible limits for fluoride contamination; it is 1.5 mg/L, the highest range. Skeletal and dental fluoroses, bone fracture risk, immune deficiency, and cancer are consequences of fluoride on public health [4]. The pollutants have been classified into organic and inorganic compounds for their removal as adsorbates by activated carbons. In general, organic compounds are nonpolar or slightly polar and therefore require oxygen-free activated carbons, devoid of polar surface groups, for their removal.

On the other hand, inorganic compounds are generally polar, so these will be adsorbed preferably by activated carbons associated with polar surface chemical groups. The acidic groups on the activated carbon surface dissociate into anionic groups in the high pH range. These anionic groups depress the adsorption of anionic compounds by electrostatic repulsion and promote the adsorption of cationic compounds by electrostatic attraction. Fluorosis affects almost 1.1 crore individuals in 160 districts across 16 states in India [5], with various levels between 1.5 ppm and 16 ppm. Fluoride deposition over the surface of bones and cartilage is the cause of fluorosis. Metabolic abnormalities, discoloured teeth and dental cavities, rigid joints, curved skeletal anatomy, and even paralysis have all been reported [6]. Scientists and researchers from the University of Bordeaux, France, have surveyed 3578 people and concluded that if the range of fluoride exceeds 1.8 ppm in drinking water, aged people above 65 years are affected with hip fractures. Specialists from Glasgow University discovered a significant reduction in white blood cells in fluorosis patients. Immunity deteriorated, and major illnesses resulted. Also, it causes the respiratory system, liver, digestive system, kidneys, excretory system, and enzyme disintegration to malfunction [7]. Nonskeletal fluorosis has several important consequences. The fluoride concentration in groundwater ranges in Dharmapuri and Salem districts, followed by Madurai, Dindugal, Trichy,

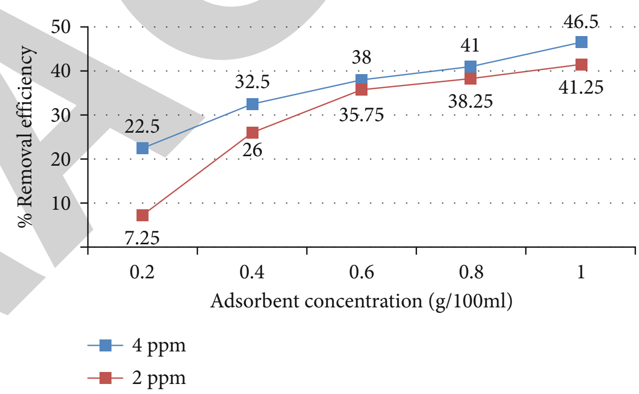

Figure 2: Neem powder adsorbent with initial fluoride concentration 2 ppm and 4 ppm.

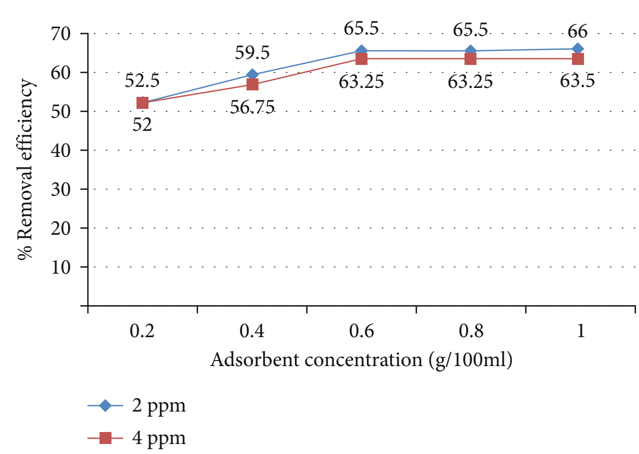

Figure 3: Rice husk powder adsorbent with initial fluoride concentration 2 ppm and 4 ppm.

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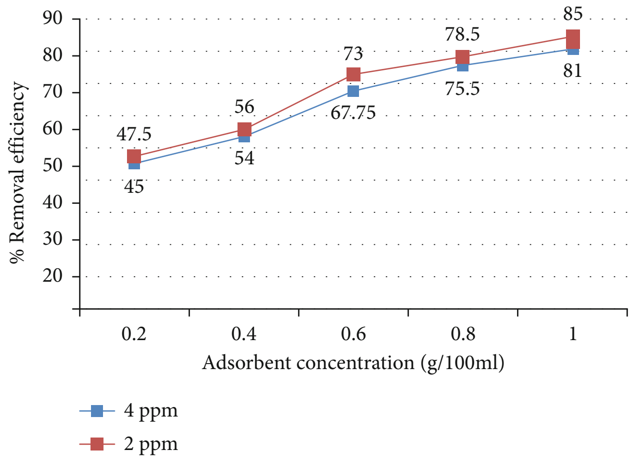

Figure 4: Coconut husk adsorbent with initial fluoride concentration 2 ppm and 4 ppm.

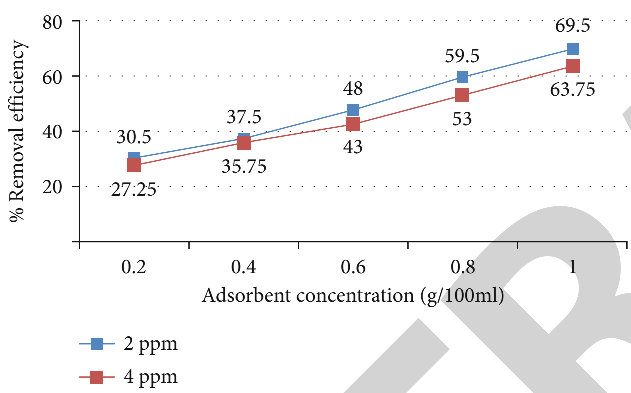

Figure 5: Coconut shell charcoal adsorbent initial fluoride concentration 2 PPM and 4 PPM.

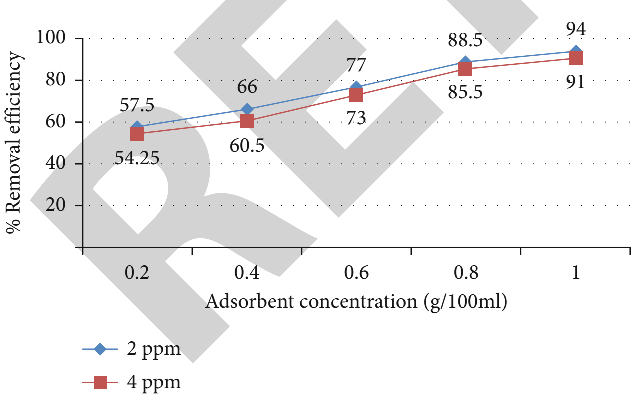

Figure 6: Neem stem charcoal adsorbent initial fluoride concentration 2 PPM and 4 PPM.

Chidambaram, and Coimbatore districts. Tirunelveli, Pudukkottai, and Remand districts in Tamil Nadu. 75% of students and kids have dental fluorosis [8]. Many people were affected by dental & skeletal fluorosis which led them to mottling teeth, osteosclerosis in the pelvis, chronic joint pain, and vertebral column [9]. Dental fluorosis is detected in various forms like discolouring, blackening, and chalk white teeth, which expose the exposure to fluoride in the growing stage of teeth in children [10]. The organic pollutants present in water constitute various organic compounds such as cationic and anionic organic compounds, nitro compounds, phenols, organic acids, amino compounds, halomethanes, pesticides, and dyes. These effects were more severe with a duct above 35 [11]. Defluorination may help to reduce the fluoride content in some countries. In developing and underdeveloped countries, the people and NGOs depend on bioadsorbents [12].

This study aims to provide purified drinking water for the locality, remove fluoride using materials that are available in nature, determine the effective natural adsorbent, and determine the optimum concentration of adsorbent for the effective removal of fluoride.

2. Evolution of Work

Vijay et al. conducted an in-depth survey in Pennagaram in four schools having 660 students from 5 to 13 age in January 2016; dental fluorosis affects more than 75% of people. This study shows an increasing tendency of this disease, common among the 10-12 age group students with above the WHO level 1.5 ppm [13]. Amarnath et al. carried out a study in the Dharmapuri district with a comprehensive study from the age of 2 to 25 years, which they were affected with skeleton mottling [14]. Sivarajasekar et al. surveyed Salem, Tamil Nadu had a specific study with 970 students including 630 boys and remaining girl students and found 36% of them were affected with dental decay [15]. Gayathri et al. compared various materials for the removal of fluoride; their investigation had some experimental works which inexpensive and safe methods for removing fluoride [16]. Gautam and Singh have prepared activated carbon materials using neem leaves and peepal leaves as adsorbents; they found a removal efficiency of six adsorbents and found activated neem is more efficient [17].

Bharali and Bhattacharyya carried out the experiments and concluded a few important results. The natural bioadsorbents available in and around the places have more efficient removal of fluoride and are more effective than other sophisticated methods. They tried treated neem and mango leaf powder with various concentrations and contact timings. Results gave a practical optimum value in removal efficiency within the 2.0 and 8.0 pH limits [18]. Hokkanen et al. compared various inorganics, organic, and natural adsorbents from various studies and found better materials. The environment, contamination, industrial effluent, natural water flow under the ground, water and soil pH level, temperature, and human activities mostly affect fluoride contamination. Metal ores and bioadsorbents have a natural capacity to observe fluoride with some certain limitations [19]. Islamuddin et al. studied various technologies to remove fluoride in the groundwater. In this paper, the coconut husk is used for defluoridation as a natural adsorbent, and it is analyzed that 86% of fluoride removal is possible. So the coconut husk is cheaper for the removal of fluoride in water; it has 86% efficiency of removal efficiency [20].

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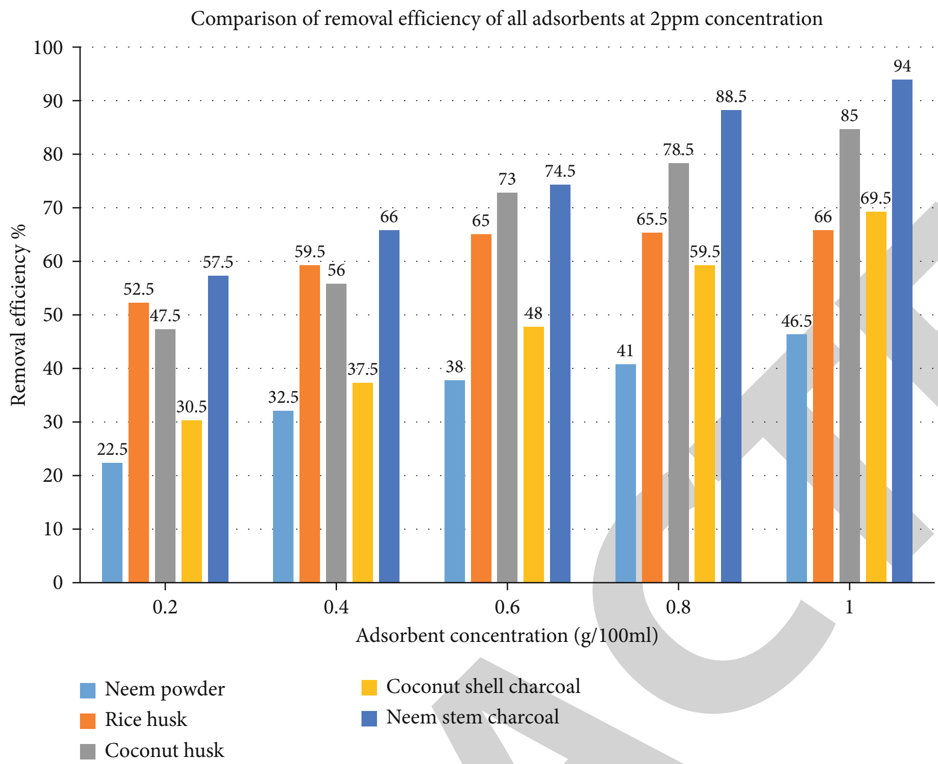

Figure 7: Comparison of removal efficiency of all adsorbents at 2 ppm.

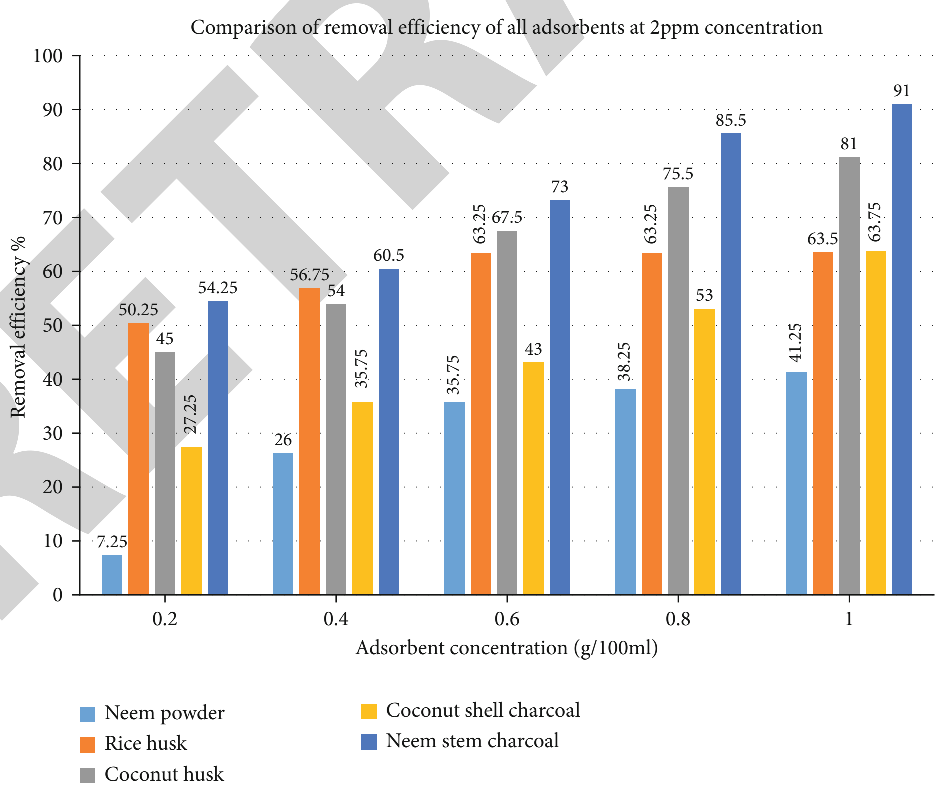

Figure 8: Comparison of removal efficiency of all adsorbents at 4 ppm.

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Table 1: Fluoride removal efficiency in groundwater.

Adsorbent	Final fluoride concentration (ppm)	Removal efficiency (%)
Neem powder	0.96	44.18
Rice husk powder	0.61	64.53
Coconut husk	0.3	82.55

Table 2: Removal efficiency comparison between stock solution and groundwater.

Adsorbent	Removal efficiency (%)	
	Stock solution	Groundwater
Neem powder	46.50	44.18
Rice husk powder	66.00	64.53
Coconut husk	85.00	82.55
Coconut shell charcoal	69.50	68.02
Neem stem charcoal	94.00	91.27

Karunarathne and Amarasinghe studied the percentage removal of fluoride content from groundwater using sugarcane bagasse. It gave an excellent fluoride removal efficiency of 86% from the drinking water of 5 g/l dose at 323 K temperature and was confirmed by the experiments [21]. Panchore et al. reviewed about few low-cost adsorbents like tea ash, pumic, neem stem charcoal, bleaching powder, sawdust neem, pipal, activated neem leaves, bark of babool in removing fluoride in aqueous, and synthetic solutions; in these studies, the neem stem charcoal has the maximum rate of efficiency in removal of fluoride with 94% [22]. Ranjit et al. studied the fluoride removal from groundwater with the Modified bark of Terminalia Chebula (MTC). The results conclude that the Modified bark of Terminalia Chebula (MTC) has a good fluoride removal capacity with the optimum dose with an initial concentration of fluoride 2 g/L and 5 mg/L and 360 minutes as optimum contact time; in pH 6-8, the capacity of adsorption was peak [23]. Bandewar et al. had a brief study on granular activated carbon (GAC) from coconut shells and charcoal by continuous fixed-bed column in the defluoridation of water. Maximum fluoride removal of 72% in 4 ppm concentration and 4 ml/min flow, and the adsorbent dose is about 6 cm [24]. Bharali and Bhattacharyya used neem in the form of powder to remove fluoride from groundwater. The neem leaves were dried and powdered to be used as the bio adsorbent to remove fluoride. The effects of temperature, pH, and contact time were investigated, and fluoride removal efficiency at pH of 2 was 74.25% with a contact time of 300 minutes [25].

3. Materials and Methods

In this study, local agricultural waste products and their by-products were estimated and cross-verified for their availability, reducing the raw material cost and easy accessibility. In this case, neem, mango, banana, sugarcane, jack fruit, cashew, rice, paddy, cereals, coconut, palm, wheat, sunflower, eucalyptus, and many more agri products and their details were collected and analyzed. In these products, we found that the neem, rice, and coconut plants are in more quantity than others, giving a continuous supply of by-products and waste products throughout the year [26]. We gave more importance to the sustainability of the environment; in any case, we should not recommend growing or importing new organic materials outside the Dharmapuri district and its surroundings so that we are specific in the selection of materials [27]. This selected material has a huge quantity of by-products used for other purposes. So, we preferred this for our study.

3.1. Fluoride Stock Solution. The project uses 2 ppm-10 ppm stock solutions to find the optimum material. The stock solutions were prepared as per the procedure for 10 ppm, 4 ppm, and 2 ppm.

3.2. Preparation of Adsorbents. The adsorbents are prepared as per the procedure; they are in charcoal form and powder form.

3.3. Reagents. Reagents were prepared and used; they are SPADNS, zirconyl acid, and acid zirconyl-SPADNS reagent.

3.4. Standard Curve Preparation. Standard fluoride solution is prepared between 0 and 1.40 mg/lt. By adding 50 ml of distilled water with standard fluoride solution, 10 ml of acid-zirconyl and SPADNS was mixed and taken in the pipette. Well stirring is done to avoid the contamination of two different solutions. A photometer is used to find the measurements of the solution by setting it as per the procedure. The readings absorbed for a sample are compared with the standard solution [28]. Figure 1 shows the curve of the concentration and absorbance.

4. Experiment Using Stock Solution

The prepared adsorbents are used in the following concentrations with the respective contact time. Fluoride concentration taken as constant 2 ppm, 4 ppm, and adsorbent concentration of 0.2, 0.4, 0.6, 0.8, and 1.0 g for 100 ml sample for 10, 30, and 60 minutes as contact time period.

4.1. Neem Powder Adsorbent. The neem powder adsorbent reaches a maximum efficiency of 46.5% at the adsorbent concentration 1 g/100 ml at 1 hour contact time. The neem powder adsorbent reaches a maximum efficiency of 41.25% at the adsorbent concentration 1 g/100 ml at 1 hour contact time [29].

Figure 2 is plotted for various adsorbent concentrations at 1 hour contact time. It can be seen that decreasing in removal efficiency with the rise in the concentration of fluoride.

4.2. Rice Husk Powder Adsorbent. The rice husk powder adsorbent reaches a maximum efficiency of 66% at the adsorbent concentration of 1 g/100 ml at 1 hour contact time. It can be seen that the removal efficiency remains constant from 0.6 g/100 ml adsorbent concentration [30]. The rice husk powder adsorbent reaches a maximum efficiency

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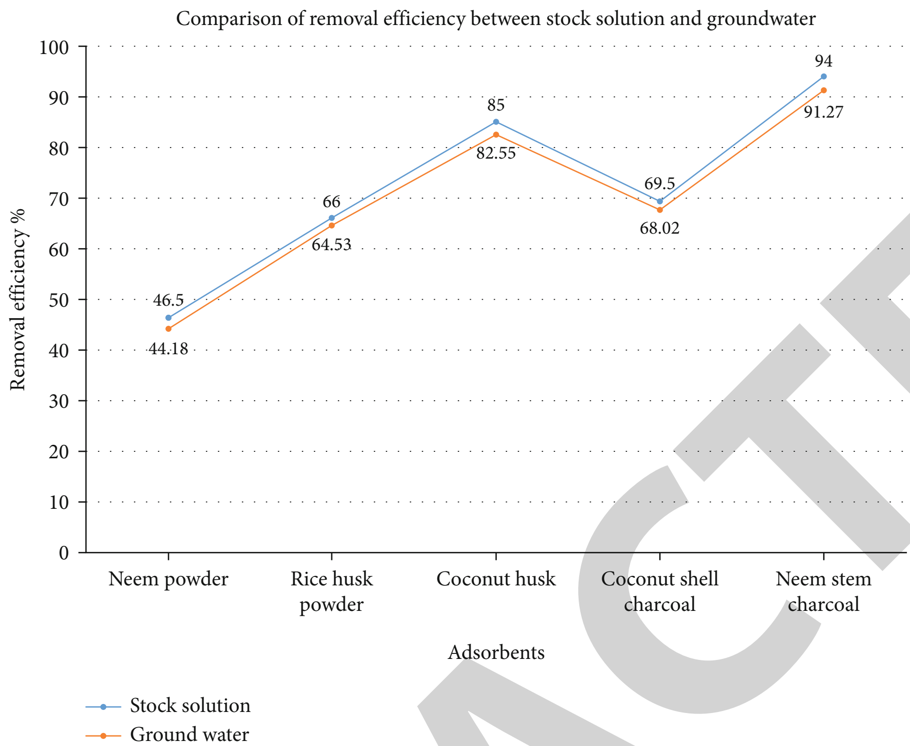

Figure 9: Comparison graph of removal efficiency between stock solution and groundwater.

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Table 3: Adsorbent concentration and contact time for treating groundwater.

Adsorbent	Adsorbent concentration (g/100 ml)	Contact time	Final fluoride concentration (ppm)	Removal efficiency (%)
Neem powder	1	1 hour	0.96	44.18
Rice husk powder	0.2	10 minutes	0.92	46.51
Coconut husk	0.2	30 minutes	0.98	43.02
Coconut shell charcoal	0.6	10 minutes	0.98	43.02
Neem stem charcoal	It cannot be used for treating this groundwater as the fluoride content goes below 1 ppm (according to bis, fluoride content in water should be 1 ppm).			

of 63.5% at the adsorbent concentration of 1 g/100 ml at 1 hour contact time. It can be seen that the removal efficiency remains constant from 0.6 g/100 ml adsorbent concentration [31].

Figure 3 is plotted for rice husk powder adsorbent with initial fluoride concentration 2 ppm and 4 pp. It can be seen that decreasing removal efficiency is a rise in the concentration of fluoride [32].

4.3. Coconut Husk Adsorbent. The coconut husk adsorbent reaches a maximum efficiency of 85% at the adsorbent concentration of 1 g/100 ml at 1 hour contact time. The coconut husk adsorbent reaches a maximum efficiency of 81% at the adsorbent concentration of 1 g/100 ml at 1 hour contact time [33]. The coconut husk adsorbent touches a maximum efficiency of 81% at the adsorbent concentration of 1 g/100 ml at 1 hour contact time [34]. Figure 4 is plotted for various adsorbent concentration at 1 hour contact time for coconut husk adsorbent with initial fluoride concentrations of 2 ppm and 4 ppm [35]. It can be seen that there is a decrease in efficiency with the increase in concentration of fluoride.

4.4. Coconut Shell Charcoal Adsorbent. The coconut shell charcoal adsorbent reaches a maximum efficiency of 69.5% at the adsorbent concentration of 1 g/100 ml at 1 hour contact time [36]. The coconut shell charcoal adsorbent reaches a maximum efficiency of 63.75% at the adsorbent concentration of 1 g/100 ml at 1 hour contact time [37]. Figure 5 is plotted for various adsorbent concentrations at 1 hour contact time for coconut shell charcoal adsorbent initial fluoride concentration 2 PPM and 4 PPM. It shows a decrease in efficiency with the fluoride concentration increase [38].

4.5. Neem Stem Charcoal Adsorbent. The neem stem charcoal adsorbent reaches a maximum efficiency of 94% at the adsorbent concentration 1 g/100 ml at 1 hour contact time. The coconut shell charcoal adsorbent reaches a maximum efficiency of 91% at the adsorbent concentration 1 g/100 ml at 1 hour contact time [39].

Figure 6 is plotted for various adsorbent concentrations at 1 hour contact time for neem stem charcoal adsorbent initial fluoride concentration 2 PPM and 4 PPM. It shows a decrease in efficiency concerning concentration increase [40]. Neem stem charcoal has the highest removal efficiency, and neem powder has the lowest [41].

Figure 7 is plotted for all adsorbents at 1 hour contact time and a comparison of all adsorbents' removal efficiency at 2 ppm. As we can see, neem stem charcoal has the highest removal efficiency, and neem powder has the lowest removal efficiency [42].

Figure 8 is plotted for all adsorbents at 1 hour contact time and a comparison of all adsorbents' removal efficiency at 4 ppm. As we can see, neem stem charcoal has the highest removal efficiency, and neem powder has the lowest removal efficiency [43].

5. Experiments Using Groundwater Sample

Groundwater sample location: Pennagaram City, Dharmapuri District, Tamil Nadu [44]; borewell/open wells have used to collect samples, their initial fluoride concentration is 1.72 ppm, turbidity is 1NTU and p^H – 6.9 [45].

5.1. Testing of Water for Fluoride from Groundwater after Using Adsorbents. The testing of fluoride removal from water is carried out using an adsorbent concentration of 1 g/100 ml and a contact time of 1 hour shown in Table 1.

Table 2 shows the comparison of the removal efficiency of various adsorbents in stock solution and groundwater.

Table 2 exposed the comparison graph of removal efficiency between stock solution and groundwater. Figure 9 identified that the removal efficiency of fluoride in groundwater is less than the stock solution. This is due to the other contaminants present in the water collected [46]. Therefore, according to the required final fluoride concentration, the adsorbent concentration and contact time are selected accordingly for the various adsorbents [47].

5.2. Comparison Results. Organic materials have the property of absorbing contaminations. Still, the efficiency and contact time may not be predictable [48], so we have to prepare the organic materials into an activated carbon source that can actively adsorb the contaminations in limited contact timings [49]. Hence, this study picks some selective natural materials which are plentily available as organic carbon source as a raw material with a small preparation in a controlled temperature to activate the carbon source as activated carbon; this activation accelerates the adsorbent capacity of the carbon source in short time duration so that contact time is comparably lesser than normal organic adsorbents [50].

The adsorbents proved to remove fluoride at a very high level with groundwater. The removal efficiency of all adsorbents kept increasing except for rice husk [51]. Table 3 shows the adsorbent concentration and contact time for treating groundwater. Rice husk and coconut husk have an average removal efficiency in the four materials, neem stem charcoal has the highest efficiency, and neem powder has the lowest efficiency.

6. Conclusion

The groundwater from the Dharmapuri district had a fluoride concentration of 1.72 ppm. As per the Bureau of Indian Standards, the concentration should not exceed 1.5 ppm, and it should not be lesser than 1 ppm; keeping this in mind, the neem stem charcoal which has higher efficiency in removing fluoride can be used in extensive environments, but in this selected place, it reduces the concentration even below 1 ppm, which relay below the standard level. The other adsorbents can be used with concentration and contact time ensuring a safer groundwater consumption range.

This study considers a viable practice for removing contamination which should be easy to work and materialize with ease; so, just adopting a simple practice of stirring the carbon adsorbent material with contaminated water can be achieved, as these materials are available in and around the villages and small towns of Dharmapuri district, which can be easily accessible and available in affordable price, people can utilize this method and material extensively.

Data Availability

The data used to support the findings of this study are included within the article. Should further data or information be required, these are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Acknowledgments

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