American Journal of Chemical Engineering
2025, Vol. 13, No. 2, pp. 46-52
https://doi.org/10.11648/j.ajche.20251302.12

Research Article

Copper Oxide Nanoparticles Made from Thespesia Populnea and Activated Charcoal to Remove Fluoride from Groundwater: Structural Analysis

Pankaj Sen*, Rajeev Mehta, Preeti Mehta, Nirma Dhaker

Department of Chemistry, Sangam University, Bhilwara, India

Abstract

The objective of this research was to create methods that are efficient and economical for eliminating fluoride from groundwater. Water, which is the most essential element for maintaining life on our planet, has been seeing a gradual decline in quality as a result of India's growing population, increasing industrialisation, and increasing use of pesticides in agricultural practices. Fluoride ions, which may be found in both groundwater and surface water, are the most significant contributor to water deformation. As a result of studying the study, it was shown that fluoride is the most prevalent problem all over the world. As a result, we devised a novel method for removing fluoride concentrations from groundwater by using cow urine, nanoparticles of cooper oxide, and active charcoal that was made from Thespesia populnea. This approach resulted in a reduction in fluoride content by fifty percent, and it has also been published by the Indian Patent Office under the number 202311051829A, which is the patent application number for this technology.

Keywords

Adsorbent, Nanoparticles, Water Quality, Treatment, Parameters

1. Introduction

Water – the vital essence of existence. The provision of safe drinking water is crucial in the current progressively contaminated environment [1]. The most effective method to guarantee this is by implementing water purification by filtration [2]. Water purification refers to the systematic procedure of eliminating or decreasing the levels of unwanted substances, such as chemicals and biological pollutants, from contaminated water [3]. Major categories of water pollutants encompass a broad range of chemicals and microorganisms. Chemical and other pollutants encompass both organic and inorganic compounds [4]. A multitude of chemical compounds exhibit toxicity. Polluted potable water is a global emergency and the situation is deteriorating daily [5]. Our survival relies on uncontaminated potable water rather than the supply of food. Approximately 80% of all diseases are caused directly by waterborne organisms. The challenge of supplying the growing global population with potable water is a formidable one [6]. Research undertaken by the World Health Organisation (WHO) indicates that 80% of infectious diseases are spread through water, leading to more than 5 million deaths each year caused by contaminated drinking water. [7]. The primary hallmark of water pollution is the

*Corresponding author: pankajsunita2004@gmail.com (Pankaj Sen)

Received: 7 February 2025; **Accepted:** 27 March 2025; **Published:** 16 June 2025

existence of pathogens including bacteria, viruses, and protozoa [8]. The safety of pure water is compromised by several factors such as groundwater pollution, industrial wastewater, transportation, storage, and inadequate water sanitation. While household water treatments are crucial for enhancing the quality of drinking water, it is equally necessary to prioritize the efficient storage of the purified water to prevent the possibility of recontamination [9].

Water treatment, on the other hand, must be performed to ensure potability [10]. Many methods for removing fluoride have been developed, including filtering, the Nalgonda method, co-precipitation, adsorption, sedimentation, and precipitation [11]. The adsorption method is the cheapest and easiest to use, whereas the others are extremely expensive, produce poisonous compounds, produce excess sludge, have flaws, and are a complex approach [12]. Adsorption has become a popular method for removing fluoride in recent years, although the ion-exchange technique may remove up to 90–95% of fluoride, the resin regeneration chemical reagents into the environment, and the treated water has very low pH and high chloride levels [13]. The process of adsorption is often regarded as the most efficient and feasible approach for eliminating fluoride from drinking water. [14]. Activated alumina, activated carbon, bone charcoal, oxides, and other inexpensive materials are examples of fluoride adsorbents. [15]. This treatment is cost-effective and can eliminate fluoride at a safe concentration [16]. Temperature, pH, and adsorbent dose, on the other hand, have a significant impact on fluoride removal [17]. Furthermore, this method requires a regeneration step once the adsorbents have been exhausted, which may reduce the adsorption ability of the adsorbents [18].

In line with the recommendations from the world health organization, with a good capacity of removal and regeneration, but with relatively law cost are required [19]. The most used adsorbent material is metal nanoparticles, other materials used are activated charcoal, bone char, mineral rocks, biosorbents, or residues, which present low costs and high local availability, as is the case of sludge [20].

Phenols and flavonoids, which are present in many plant components such as shoots, leaves, stems, flowers, roots, and fruits, are the most significant phytochemicals in plants. These phenolic compounds have ketone and hydroxyl groups, which help with iron chelation and lead to their potent antioxidant properties. The nanoparticles (NPs) produced using this environmentally friendly process exhibited enhanced stability, were less prone to agglomeration and deformation, and permitted the adsorption of phytochemicals onto their surface, hence augmenting the NPs' response rate. A typical method for creating Cu and CuO NPs involves heating a mixture to a specific temperature while continuously stirring it for a predetermined amount of time, combining a known concentration of plant extract with a known precursor concentration (given Figure 1).

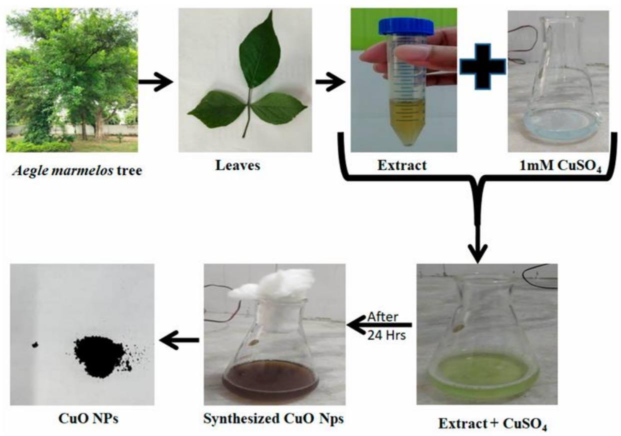

Figure 1. *Green synthesis of CuO Nano particle.*

In this research cost-effective and easily available materials were used to produce natural adsorbent- charcoal, activation of these charcoal with the help of calcium chloride solution and cow urine after the activation of charcoal it were combined with copper nanoparticles for the removal of fluoride from drinking water. Activated charcoal of different types of plant stems, bark, and seeds was used, but the seeds of Hibiscus Populeneous show extremely good result regarding fluoride removal. XRD pattern of activated charcoal and copper nanoparticles also done by the material research centre MNIT Jaipur.

2. Material and Methods

2.1. Adsorbent Used for Fluoride Removal

Thespesia Populnea (Figure 2): It is a small tree with tiny peltate scales covering petioles, pedicels, calyx, and younger branches [21]. Cordate, ovate, acuminate, smooth, leathery, whole, or sinuous leaves on long stalks, axillary, stalked flowers, the petiole is shorter than the peduncle, five oblong-lanceolate, deciduous segments of the epicalyx, each as long as or slightly longer than the calyx, which has five teeth and is fashioned like a cup [22]. Nearly two inches long, corolla is four times longer than a calyx. Fruit with five cells, a depressed shape, a slight beak, and an opening at the top that is either slight or indehiscent [23]. Large, compressed seeds with a rounded top and two in each fruit cell; Testa pubescent and Nervosa striate.

Source: https://www.uniprot.org/taxonomy/3638

Figure 2*. Source plant – Thespesia Populnea (Paras Pipal).*

The following method was used to form activated charcoal from the above-starting materials.

2.2. Activated Charcoal

The starting materials were heated in the absence of air in a copper container at 300 ℃ in a heating oven, charcoal produced by this method than charcoal washing with water and then treated with the cow unrein for 2h. Charcoal was dried in sunlight for two days, which is known as the first activation of charcoal after this second activation, by treating the activated charcoal with calcium chloride solution (prepared by dissolving 20g of calcium chloride in 1000ml of water [24] for 1h to produce activated charcoal, which is now ready for use in the fluoride removal process. In the removal process, water samples were treated with the prepared activated charcoal one by one using a magnetic starrier and hot plate in batch forming at different time intervals of 20, 30, and 60min for each activated charcoal by repeating each time interval.

2.3. Cooper Oxide Nanoparticle with Activated Charcoal

In this process cooper nanoparticles formed by the chemical method with cooper sulphate and ascorbic acid with constant starrier at hot plate and wash with ethanol and separate out with evaporation process [25]. In this method prepared nanoparticles combine in equal proportion i.e., 1:1 with activated charcoal.

2.4. Process of Fluoride Removal

Figures 3-6 showing the work done in the laboratory. In this process water sample having fluoride content treated with the active charcoal on magnetic starrier for regular time interval, in this process fluoride measured by digital fluoride meter before the treatment and after the treatment again check the fluoride with the help of fluoride meter. The combination of double activated charcoal and mixture of charcoal and CuO nanoparticles.

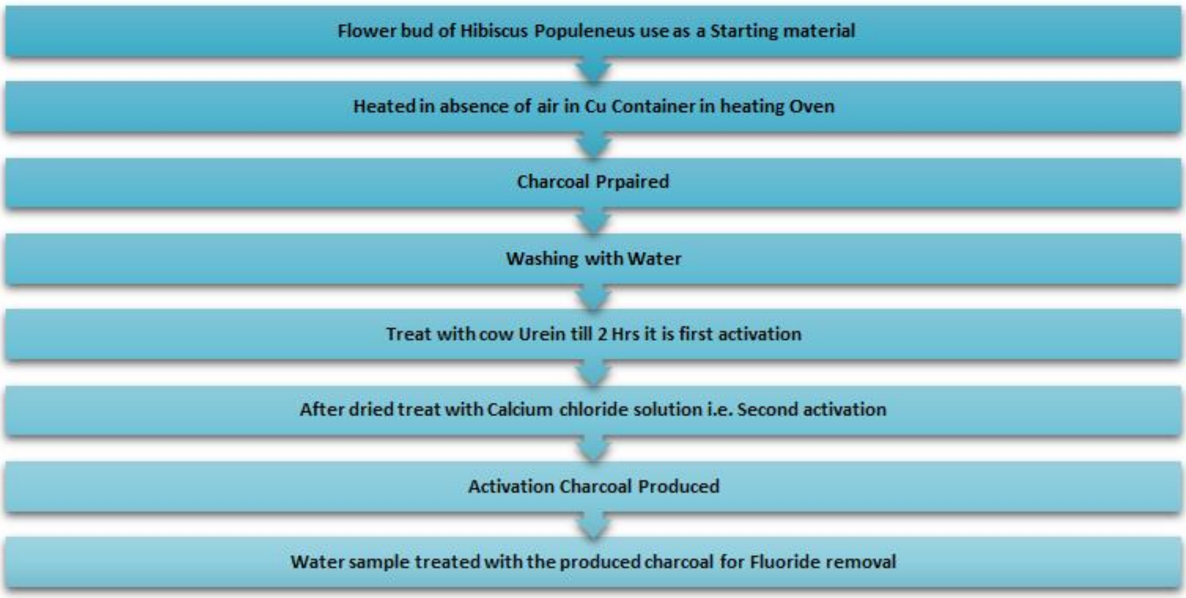

Figure 3*. Flow chart to produce activated charcoal.*

Figure 4. *Plant source and CuO nanoparticle.*

Figure 5. *Activation with cow urine and treatment with CuO nanoparticle.*

Figure 6. *Water sample after treatment.*

3. Result and Discussion

The result (Table 1) was surprising with both removal adsorbents one was only activated charcoal and another was a mixture of activated charcoal and cooper nanoparticles which is shown following tabulation- Table 1 show that the percentage exclusion of the fluoride with the treatment of active charcoal in 30 minutes was 27.90% and in 60-minute 44.44% exclusion, Cu nanoparticles + active charcoal showed 37.93% exclusion in 30 minutes and 50% exclusion of fluoride in 60 minutes.

Table 1. *Result of fluoride removal based on time.*

Time	Activated Charcoal		Removal percentage	Activated charcoal + Cu Nano Particles (1:1)		Removal percentage
	Before treated	After treatment		Before treated	After treatment	
30 Minute	4.3	3.1	27.90%	2.9	1.8	37.93%
60 Minute	2.7	1.5	44.44%	2.4	1.2	%

On the basis of above table, it is clear that the removal of fluoride gives the significant result and show the success of this work.

3.1. Structural Characterization of Copper Nanoparticles

3.2. UV-Visible Spectrum Studies

The recorded UV-visible spectrophotometer spectrum is displayed in Figure 7. The peak that emerged closer to 562nm is thought to have originated from surface plasmon vibrations of CuO NPs.

Figure 7. *Before treatment and After treatment.*

3.3. FTIR Spectrum Studies

Hibiscus populenious plant extract was used to create CuO NPs, and the FTIR spectrum of these CuO NPs is displayed in (Figure 8). Alkyl-H stretching alcohols and phenols are associated with the band at 3447 cm-1. First-order amines' N-H bending is indicated by the bands at 1527 and 1546 cm-1. C-N stretching of amines is represented by the bands at 1054 cm-1, 1032 cm-1, and 1016 cm-1. C-H stretching may be seen in the peaks at 771 cm-1 and 636 cm-1. The produced CuO NPs are therefore expected to be encircled by proteins and metabolites, such as terpenoids with functional groups of alcohols, ketones, amines, and carboxylic acids, based on the FTIR information.

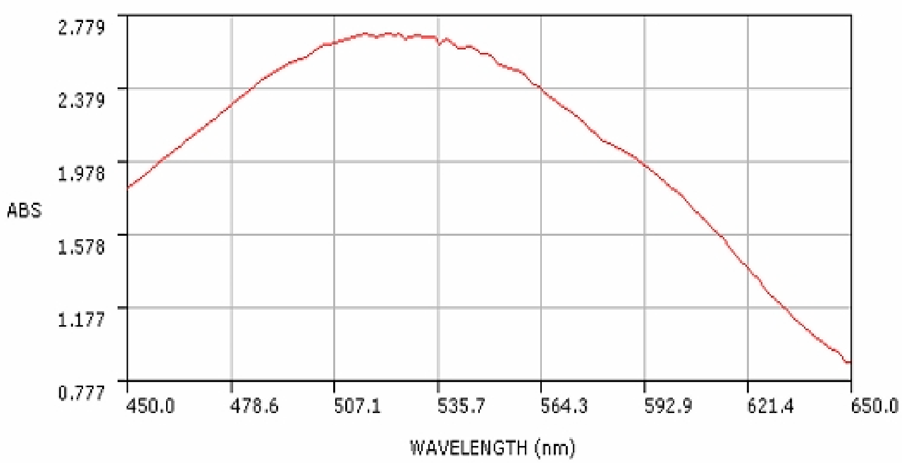

Figure 8. *UV Visible spectrum of CuO Nanoparticles.*

3.4. XRD Study of Cu Nanoparticle

Figures 9 and 10 show the graphical presentation of activated charcoal and copper nanoparticles. The XRD pattern of activated charcoal and mixture of activated charcoal and activated charcoal is done by the materials research centre MNIT Jaipur, which shown in following information about the activated charcoal and CuO nanoparticle.

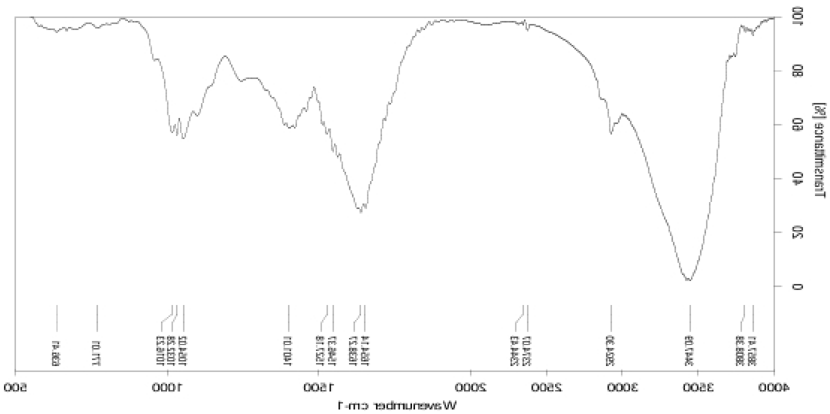

Figure 9. *FTIR Spectrum of CuO Nanoparticles.*

3.5. Activated Charcoal

At the 2θ = 5.2 degree is the starting angle and 89.98 degree is the end position angle, with the diffractometers system is XPERT-PRO.

3.6. Mixture of Activated Charcoal and CuO Nanoparticle

At 2θ 5.0 to 89.98 degree, the peak position found at the 2θ, 43.53, 50.47, and 74.15 degree with the height of 4584, 1708, and 826 cts, having d- spacing 2.08732, 1.80822, and

1.27876 Å respectively.

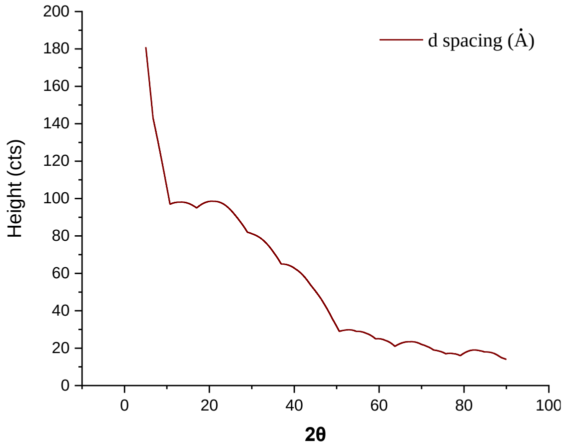

Figure 10. XRD pattern of activated charcoal.

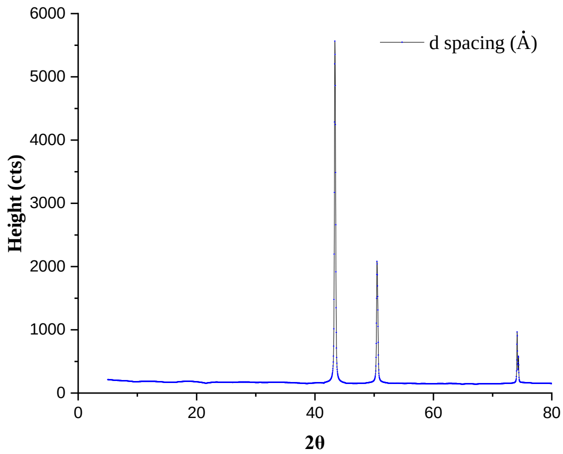

Figure 11. XRD pattern of CuO nanoparticles.

4. Conclusion

Modern civilization, industry, urbanization, and population growth have contributed to the rapid depletion of water supplies. A comprehensive and thorough investigation into the water quality is required in light of the current scenario of declining water quality to create a solid database. Cooper oxide nanoparticles and Hibiscus populneus (Paras Pipal) charcoal were found to be effective adsorbents for defluorination of polluted drinking water sources. Above bio adsorbent proved successful in removing fluoride ions from an aqueous solution of 4.8 ppm, 2.7 to 1.5, and 2.9mg/l respectively. This result and technique were also Published in with the Indian patent journal with the application number 202311051829A.

Abbreviations

CuO	Cooper Oxide
XRD	X-Ray Differation
IR	Infrared Spectroscopy
PPM	Parts Per Milion

Author Contributions

Pankaj Sen: Formal Analysis, Methodology, Writing – original draft, Writing – review & editing

Rajeev Mehta: Supervision, Validation

Preeti Mehta: Formal Analysis, Investigation, Visualization

Nirma Dhaker: Formal Analysis, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Mishra, Rakesh Kumar. "Fresh water availability and its global challenge." British Journal of Multidisciplinary and Advanced Studies 4.3 (2023): 1-78.

[2] Bolisetty, Sreenath, Mohammad Peydayesh, and Raffaele Mezzenga. "Sustainable technologies for water purification from heavy metals: review and analysis." Chemical Society Reviews 48.2 (2019): 463-487.

[3] Arman, Nor Zaiha, et al. "A review on emerging pollutants in the water environment: Existences, health effects and treatment processes." Water 13.22 (2021): 3258.

[4] Ethiraj, Selvarajan, Melvin S. Samuel, and S. M. Indumathi. "A comprehensive review of the challenges and opportunities in microalgae-based wastewater treatment for eliminating organic, inorganic, and emerging pollutants." Biocatalysis and Agricultural Biotechnology (2024): 103316.

[5] Khan, Shamshad, et al. "Emerging contaminants of high concern for the environment: Current trends and future research." Environmental Research 207 (2022): 112609.

[6] World Health Organization. "State of the world's sanitation: an urgent call to transform sanitation for better health, environments, economies and societies." (2020).

[7] World Health Organization. "Safer water, better health." (2019).

[8] Cieślik, Bartłomiej Michał, Jacek Namieśnik, and Piotr Konieczka. "Review of sewage sludge management: standards, regulations and analytical methods." Journal of cleaner production 90 (2015): 1-15.

[9] Gai, Wei-Zhuo, and Zhen-Yan Deng. "A comprehensive review of adsorbents for fluoride removal from water: Performance, water quality assessment and mechanism." Environmental Science: Water Research & Technology 7.8 (2021): 1362-1386.

[10] Sen, P., and R. Mehta. "Analysis of water quality parameters of some village of Deoli Tehsil (Tonk)." *RNT journal of current Discovery in Chemistry* 4, no. 2 (2019): 14-17.

[11] Jagtap, Sneha, et al. "Fluoride in drinking water and defluoridation of water." Chemical reviews 112.4 (2012): 2454-2466.

[12] Kennedy, Kalebaila K., Kenneth J. Maseka, and Misheck Mbulo. "Selected adsorbents for removal of contaminants from wastewater: towards engineering clay minerals." Open Journal of Applied Sciences 8.8 (2018): 355-369.

[13] Khan, A., Rashid, A., Younas, R. et al. A chemical reduction approach to the synthesis of copper nanoparticles. Int Nano Lett 6, 21–26 (2016). https://doi.org/10.1007/s40089-015-0163-6

[14] Lindley, John. Flora medica: a botanical account of all the more important plants used in medicine, in different parts of the world. Cambridge University Press, 2011.

[15] Mannina, G., Gulhan, H., & Ni, B. J. (2022). Water reuse from wastewater treatment: The transition towards circular economy in the water sector. Bioresource Technology, 127951.

[16] Meena, Inder Singh. "FLUORIDE EFFECTS ON HUMAN SOCIETY." JOURNAL OF HEALTHCARE AND LIFE-SCIENCE RESEARCH 2.7 (2023): 37-44.

[17] MiarAlipour, Shayan, et al. "TiO_2/porous adsorbents: Recent advances and novel applications." Journal of hazardous materials 341 (2018): 404-423.

[18] Mohan, Dinesh, and Charles U. Pittman Jr. "Arsenic removal from water/wastewater using adsorbents—a critical review." Journal of hazardous materials 142.1-2 (2007): 1-53.

[19] Nayeri, Danial, and Seyyed Alireza Mousavi. "A comprehensive review on the coagulant recovery and reuse from drinking water treatment sludge." Journal of environmental management 319 (2022): 115649.

[20] Peter-Varbanets, Maryna, et al. "Decentralized systems for potable water and the potential of membrane technology." Water research 43.2 (2009): 245-265.

[21] Pigatto, Renata S., et al. "An eco-friendly and low-cost strategy for groundwater defluorination: adsorption of fluoride onto calcinated sludge." Journal of Environmental Chemical Engineering 8.6 (2020): 104546.

[22] Rashid, Ruhma, et al. "A state-of-the-art review on wastewater treatment techniques: the effectiveness of adsorption method." Environmental Science and Pollution Research 28 (2021): 9050-9066.

[23] Sen, P., Mehta, R. & Mehta, P. Water quality assessment of Banas River, eastern-south region of Rajasthan, using water quality index. *Proc. Indian Natl. Sci. Acad.* 89, 134–142 (2023). https://doi.org/10.1007/s43538-022-00145-7

[24] Turner, T., Wheeler, R., Stone, A. et al. Potential Alternative Reuse Pathways for Water Treatment Residuals: Remaining Barriers and Questions—a Review. Water Air Soil Pollut 230, 227 (2019). https://doi.org/10.1007/s11270-019-4272-0

[25] Vithanage, Meththika, and Prosun Bhattacharya. "Fluoride in the environment: sources, distribution and defluoridation." Environmental Chemistry Letters 13 (2015).