

# Effective Use of Adsorption Technique for Removal of Heavy Metals from Water – A Review

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## Abstract

*Presence of heavy metals is not acceptable in water so, this study presents removal of heavy metals from water with the use of different adsorbents, particularly agricultural waste materials. This is to develop effective and economical water treatment solutions. The hazardous effects of presence of heavy metals in water cause great risks to sources of water and health issues to humans. In regions, like Bhandara and Ambazari Lake in Nagpur, groundwater has been found containing iron concentrations significantly exceeding the permissible limit of 0.3 mg/L. Specifically, Bhandara's groundwater contains approximately 17 mg/L, while Ambazari Lake has about 1.16 mg/L. Such high levels of iron not only affect the taste and color of water but also pose health risks to the local population. The study investigates the use of coconut coir, an agricultural waste product, as a solid-phase extractor for the removal of total iron from water. Good binding property is found in coconut coir, which is capable of removing iron, also leads to economical and proven good adsorbent. Present research analyses different parameters which govern adsorption efficiency, like pH, adsorbent dosage, contact time, and initial iron concentration. It has been observed that the water having pH between 4–5 allows maximum removal of iron. With satisfactory conditions, heavy metal removal efficiency by coconut coir is 96%. For iron-contaminated water, study provides the capability of coconut coir, i.e., a good adsorbent for treatment.*

**Keywords:** Heavy-metals, carbonization, coconut coir, activated charcoal, agricultural waste materials

## INTRODUCTION

The presence of heavy metals which contaminate water leads to environmental issues, cause high risks to human health and affects the ecosystem. Industrial activities, such as mining, metal plating, battery manufacturing, and textile production, often release heavy metals, like lead (Pb), cadmium (Cd), mercury (Hg), chromium (Cr), and arsenic (As), into water bodies. For a long period, the toxic effect of heavy metals has been noticed as heavy metals are non-biodegradable and pile up in living organisms [1, 2].

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Earlier the heavy metals are removed by chemical precipitation, ion exchange, membrane filtration, and electrochemical treatment. But these methods have limitations like high handling costs, more energy requirements by generating sludge, and inefficiency for contamination with low metal concentrations [3].

Now a days, to remove heavy metals has come into view as an economical and promising method. Using solid material (adsorbent), might be natural or engineered, the process contains the accumulation of metal ions onto the surface. With

its simplicity, economy, great efficiency, and the possibility of adsorbent regeneration and metal recovery, the adsorption is approved [4].

Present study examines the effectiveness of different adsorbents to remove the heavy metals from contaminated water – particularly economy, eco-friendly materials. The project will focus on the adsorption mechanisms, factors affecting the adsorption process, and comparative analysis of adsorbent performance, with the goal of contributing to sustainable and accessible water purification technologies. The availability of clean and safe water is fundamental to human health, economic development, and environmental sustainability [5].

The cause of increased water pollution, specifically by heavy metals, is sudden growth in industrialization and urbanization. These pollutants, including lead (Pb), cadmium (Cd), mercury (Hg), chromium (Cr), nickel (Ni), and arsenic (As), are introduced into water systems through various anthropogenic activities such as mining, electroplating, metal finishing, fertilizer industries, and tanneries [6].

It is essential to take care of heavy metals, the reason is their toxicity, persistence, and bio-accumulative nature. The presence of heavy metals in water contaminates it and causes severe health issues such as kidney damage, neurological disorders, reproductive issues, and carcinogenic effects. The adverse effect on aquatic ecosystems has been observed like affecting the survival and reproduction of aquatic organisms [7].

Before detailed study some water treatment solutions were applied for removal of heavy metals from water – such as chemical precipitation, ion exchange, reverse osmosis, and membrane filtration. While effective in some cases, these methods often have major drawbacks, including high operational and maintenance costs, the need for complex infrastructure, limited selectivity, and secondary pollution from sludge or chemical waste [8].

*The Adsorption* has proved that it is a technique with high capability than other methods to remove heavy metal and the reason is its simplicity, economy, great efficiency, and acceptability. The process involves the accumulation of metal ions onto the surface. Different adsorbents have been examined like activated carbon, clays, zeolites, agricultural wastes (e.g., coconut shell, rice husk, sawdust), industrial by-products, and biochar [9].

Recent research efforts have focused on improving the performance of low-cost and eco-friendly adsorbents, as well as modifying their surface properties to enhance adsorption capacity and selectivity [10].

- Metabolism in human body is affected by heavy metals that cause bad effects those are arsenic, lead, mercury, cadmium and uranium and toxic in nature.
- With high concentration leads to acute toxicity and causing acute health conditions.
- The increasing trends in environmental contamination and human health issues are raised using heavy metals in various industries and agricultural activities.
- Owing to the various activities for industrialization, heavy metals are released into the environment.
- In India, great population who lives in rural area are not capable to use water filters or water treated water bottles and, therefore, drinking water is a big issue in India. To address this issue, numerous initiatives have been undertaken to make clean water an affordable and accessible resources for all.
- Every household should have the ability to create its own water purification system. The primary goal of developing low-cost purification technologies should be to empower individuals to produce safe drinking water independently.
- The design of any economical water filtration model should focus on minimal energy consumption, low maintenance, cost-effectiveness, environmental sustainability, and ease of

implementation. Additionally, it should be possible to construct such systems using locally available materials and craftsmanship. This approach not only promotes hygiene and public health but also contributes to the nation's social and economic development.

- In certain regions, people have adopted simple yet effective methods such as using plastic bottles with open ends. These bottles are filled with filtration layers – typically a layer of bone char sandwiched between layers of sand and pebbles. Water passed through this arrangement undergoes significant purification, effectively removing sediments and microbial contaminants (Table 1).

**Table 1.** Hazardous effects of some heavy metals.

Heavy Metal	Toxic Effects
Arsenic	– Skin problems (lesions, discoloration) vascular diseases – Visceral (internal organ) cancers.
Cadmium	– Kidney damage – Renal disorders – Classified as a human carcinogen.
Chromium	– Headache – Nausea and vomiting – Diarrhea Known carcinogen.
Copper	– Liver damage – Wilson's disease – Insomnia.
Lead	– Damage to fetal brain development – Kidney and circulatory system diseases.
Nickel	– Skin dermatitis – Nausea and coughing – Chronic asthma – Known human carcinogen.
Zinc	– Depression and lethargy – Neurological symptoms – Increased thirst.

## LITERATURE REVIEW

Several research in recent years have increasingly focused on the use of low-cost and environmentally sustainable materials for water purification. Studies have shown that agricultural by-products can serve as effective natural adsorbents for the removal of heavy metals such as iron from drinking and groundwater. Materials, like coconut coir and sugarcane bagasse, have demonstrated high adsorption efficiencies, achieving up to 96% and 93% removal rates, respectively, under optimal pH conditions between 4 and 5. Other agricultural residues including rice husk, peanut shells, maize cobs, sawdust, and fruit peels have also been identified as potential adsorbents capable of improving water quality at minimal cost.

Further investigations have focused on producing activated carbon from coconut shell waste through physical and chemical activation processes. The use of activating agents, such as sodium hydroxide, zinc chloride, and phosphoric acid, enhances the adsorption capacity of the carbon. Such approaches not only provide an effective wastewater treatment medium but also offer a sustainable method of utilizing abundant agricultural waste materials [11].

Several studies have highlighted adsorption as one of the most efficient and economical techniques for removing heavy metals from contaminated water. Different classes of adsorbents, including carbon-based materials, bio-adsorbents, and naturally occurring minerals, have been successfully employed for this purpose. The adsorption and desorption mechanisms have been extensively analyzed to optimize removal efficiency, making the process a reliable choice for large-scale water treatment systems [12].

Other research have emphasized the combined use of oxidation, coagulation, and adsorption processes for effective removal of contaminants such as arsenic, iron, and manganese. Optimization of the pH during treatment has been shown to significantly improve removal rates, demonstrating that integrated methods can be both cost-effective and efficient for practical water purification applications.

Studies on groundwater hydrogeochemistry in industrial and thermal power plant regions have revealed that ion concentrations in groundwater often exceed standard permissible limits. Seasonal variations also influence the concentration of dissolved solids and heavy metals, indicating the need for continuous monitoring and treatment to maintain potable water quality.

Investigations into the effects of landfill leachate on surrounding water bodies have shown that contamination from waste disposal sites poses a serious risk to surface and groundwater resources. Elevated iron and other metal concentrations in such areas frequently surpass recommended safety guidelines, underscoring the importance of effective waste management and leachate control measures.

Comprehensive reviews of adsorption-based water purification methods have concluded that the use of economical and naturally available adsorbent materials – such as biosorbents, activated carbon, clays, zeolites, and metal oxides – can significantly reduce heavy metal concentrations in water. Continuous contamination of water sources with heavy metals remains a global concern due to its detrimental effects on human health and environmental balance. Consequently, adsorption-based techniques have gained prominence as a sustainable, flexible, and efficient solution for water treatment applications.

## SUMMARY

- The overall study and experimentation of literature review show the possible use of filter media.
- The use of low cost adsorption technologies can result in considerable reduction of cost.
- Sustainable use of adsorbent material is beneficial for filtering media.
- The use of adsorbent material to reduce heavy metal from water.

## OBJECTIVE

This paper aims to research existing water filtration methods and leverage that knowledge to design an affordable and effective household water filtration system. The primary focus is on removing iron contaminants from drinking water, a common issue in rural and remote areas. By utilizing locally available, low-cost materials, the project seeks to enhance water quality, thereby improving public health and reducing the prevalence of waterborne diseases.

- *Identification of Effective Adsorption Media:* Investigate various locally sourced, low-cost materials for their efficacy in iron adsorption. Materials of interest include bamboo charcoal, banana peels, rice husk ash, and sawdust.
- *Design of a Simple Household Filtration Setup:* Develop a user-friendly filtration system suitable for household use, emphasizing ease of assembly and maintenance. The design will incorporate the selected adsorption media to maximize iron removal efficiency.
- *Cost Estimation:* Conduct a comprehensive cost analysis of the filtration system, including the procurement of materials and construction expenses, to ensure affordability for rural households.
- *Performance Analysis:* Evaluate the filtration system's effectiveness in removing iron from water through laboratory testing and field trials. Parameters, such as iron concentration reduction, flow rate, and filter lifespan, will be assessed (Figure 1).

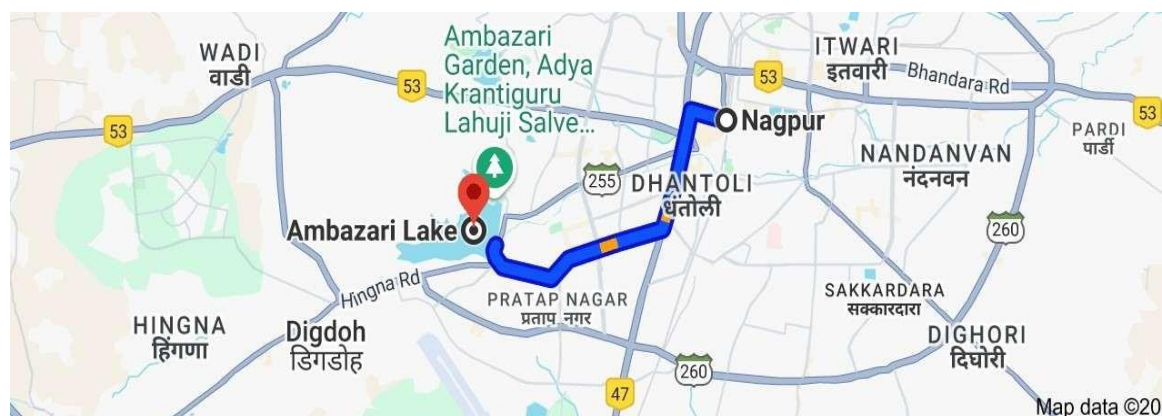


Figure 1. Site location.

## PROPOSED METHODOLOGY

### Adsorption

For the ground water filtration, to remove iron the adsorptive filtration is used with anoxic conditions where oxidation of ferrous iron is suppressed. For the study for filtration aerobic conditions in adsorption media is considered. Among some well-known adsorption media are like sand, Sugarcane bagasse, coconut coir, coconut shell, gravel, etc. The following adsorption media had been experimented here for removal of iron from drinking water.

### Aggregate

Coarse aggregate in water filtration systems, detailing its functions, such as supporting finer media, ensuring uniform water distribution, preventing media loss, facilitating proper drainage, and capturing larger particles, are to be taken care of.

### Sand

Sand serves as a fundamental component in water filtration systems, functioning as an effective medium for removing impurities and suspended solids from water. Its granular structure creates a physical barrier that traps particles, debris, and certain microorganisms as water passes through, a process known as mechanical filtration. This method relies on the spaces between sand particles to capture contaminants, allowing cleaner water to flow through. Beyond mechanical straining, sand filtration also involves processes, like sedimentation, where finer particles settle out, and biological action, which can further purify the water. These combined mechanisms contribute to the effectiveness of sand filters in producing clear and safe water.

### Coconut Coir

Coconut coir, the fibrous outer husk of the coconut, is used in water filters to remove contaminants and improve water quality. The use of adsorbent also gives filter medium and a layer which is advantageous to microbial growth. For water filtration systems coconut coir is identified as an effective and sustainable material. Its unique properties make it a valuable component in purifying water for various applications, including domestic, industrial, and agricultural uses.

### Coconut Shell (CS)

For the study to obtain activated carbon raw material, i.e., coconut shell (CS) is used. Initially deionized water is used to clean the CS and then it is dried for 48 hours at 110°C. A grinder machine is used to ground and mechanical sieve shaker is used to get samples of 1.0–2.0 mm particle size Tables 2 and 3 and Figure 2.

**Table 2.** Making of filter.

Layer	Material	Thk
Layer 1	Aggregate	12 cm
Layer 2	Sand	8 cm
Layer 3	Activated Charcoal	2 cm
Layer 4	Coconut coir	3 cm
Layer 5	Sand	3 cm

**Table 3.** Quantity of material in filter media details.

Layer	Material	Area	Thk	Volume
Layer 1	Aggregate	0.30 x 0.30 m	0.12 m	0.12 cum
Layer 2	Sand	0.30 x 0.30 m	0.8 m	0.072 cum
Layer 3	Activated Charcoal	0.30 x 0.30 m	0.2 m	0.018 cum
Layer 4	Coconut coir	0.3 x 0.30 m	0.3 m	0.027 cum
Layer 5	Sand	0.30 x 0.30 m	0.3 m	0.027 cum

## RESULT

Test on water from Ambhazari Lake, Nagpur result shown in Table 4. As per IS: 10500-2012 and

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IS: 3025.

**Table 4.** The results of Ambhazari Lake, Nagpur are as follows.

Metal	Before	After	Acceptable
Iron-Fe, mg/l	1.14	0.5	0.3



**Figure 2.** Quantity of material in filter media processing.

## CONCLUSIONS

- The simple and economical method to remove heavy metals has been proven by adsorption as it has benefits, like locally available adsorbent, can be used.
- The design of filter for the simple household setup for water filtration mainly focusing on removal of iron is easy and economical.
- The cost of construction of this adsorbent media is much less than the ceramic filter and other filter
- The analysis of filtration effectiveness in removal of iron for different filter media found satisfactory.

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## REFERENCES

1. Helmenstine AM. What adsorption means in chemistry. 2019. Available from: <https://www.thoughtco.com/definition-of-adsorption-605820> (accessed 3 Feb 2021).
2. Danish M, Ahmad T, Hashim R, Said N, Akhtar MN, Mohamad-Saleh J, et al. Comparison of surface properties of wood biomass activated carbons and their application against Rhodamine B and Methylene Blue dye. *Surfaces Interfaces*. 2018;11:1–13.
3. Castro Renata SD, Caetano L, Ferreira G. Banana peel applied to the solid phase extraction of copper and lead from river water: Preconcentration of metal ions with a fruit waste. *Ind Eng Chem Res*. 2011;50:3446–51.
4. Zaimie MZA, Sarjadi MS, Rahman ML. Heavy metals removal from water by efficient adsorbents. *Water*. 2021;13(19):2659. doi: 10.3390/w13192659.
5. Bora AJ, Dutta RK. Removal of metals (Pb, Cd, Cu, Cr, Ni, and Co) from drinking water by oxidation-coagulation-adsorption at optimized pH. *J Water Process Eng*. 2019 May;31:100839. doi: 10.1016/j.jwpe.2019.100839.
6. Singh NB, Nagpal G, Agrawal S. Water purification by using adsorbents: A review. *Environ Technol Innov*. 2018;11:187–240.
7. Ince M, Ince OK. An overview of adsorption technique for heavy metal removal from water/wastewater: A critical review. *Int J Pure Appl Sci*. 2017 Dec;3(12):1–12. doi: 10.29132/ijpas.372335.
8. Kundal P. Hydrogeochemistry of groundwater in Koradi-Khaparkheda area, Nagpur District, Maharashtra. *Geol Mag*. 2014 Jan;14:155–60.
9. Sujiono EH, Zabrian D, Zurnansyah, Mulyati, Zharvan V, Samnur, NA Humairah. Fabrication and characterization of coconut shell activated carbon using variation chemical activation for wastewater treatment application. *Results Chem*. 2022;4:100291.
10. Nandanwar AA, Ingle AU, Shende AR, Shirange VG, Shende SK, Shriwastri SR. Assessment of quality of water bodies surrounding Bhandewadi landfill site, Nagpur city. *Int Res J Eng Technol*. 2022 Mar;9(3):1607–12. doi: 10.5281/zenodo.4537354.
11. Balaji R, Sasikala S, Muthuraman G. Removal of iron from drinking/ground water by using agricultural waste as natural adsorbents. *Int J Eng Innov Technol*. 2014 Jun;3(12):43–6.
12. Junipuspita D, Nursyafarinah, Widayatno WB, Sukarto WA, Amal M, Priyono S, et al. Preparation of porous carbon made from candlenut shell (*Aleurites moluccana*) as a cathode for lithium ion capacitor. *J Phys Conf Ser*. 2019 Mar;1191(1):012020. doi: 10.1088/1742-6596/1191/1/012020.