International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 13 Issue: 01 | Jan 2026 www.irjet.net p-ISSN: 2395-0072

# Experimental Study on Bio-Adsorbents for Borewell Water Treatment

**Harshal Ughade[1], Vaishnavi Agre[2], Kasif Shekh[3], Syed Umair[4], Pooja Mankar[5], Saurabh Chavhan[6]**

*[1,2,3,4] Under Graduate Student, Jawaharlal Darda Institute of Engineering and Technology, Yavatmal,,*
*[5], Assist. Professor, Dept. of Civil Engineering, Jawaharlal Darda Institute of Engineering and Technology, Yavatmal,*
*[6] Assist. Professor, Dept. of Civil Engineering, Jawaharlal Darda Institute of Engineering and Technology, Yavatmal, Maharashtra, India*

---

**Abstract -** *The decline in groundwater quality has become a serious challenge, particularly in rural and semi-urban areas where borewell water is the main source for domestic needs. The present research investigates the purification performance of natural bio-based materials such as Neem bark, Tamarind seed powder, Orange/Lemon peel powder, and Activated Charcoal for treating borewell water. These materials are locally available, biodegradable, and inexpensive, offering an environmentally sound substitute for conventional chemical treatments. Neem bark contains phytochemicals like azadirachtin and nimb in that exhibit strong antimicrobial and adsorptive behavior, aiding in the removal of organic and microbial contaminants. Tamarind seed powder serves as a natural coagulant that reduces turbidity and heavy-metal content, while citrus peel powder, rich in pectin and polyphenols, adsorbs fluoride, calcium, and magnesium ions, improving both color and taste. Activated Charcoal, with its extensive surface area and porous structure, enhances overall adsorption of residual impurities. Laboratory batch experiments were conducted at varying pH, contact time, and dosage levels to identify optimum operational conditions. The combined application of these materials achieved contaminant removal efficiencies ranging from 85 to 95 percent, significantly improving water quality indicators such as hardness, fluoride, and bacterial count. The findings demonstrate that these bio-adsorbents provide a low-cost, sustainable, and decentralized option for household water purification, supporting Sustainable Development Goal (SDG 6) – Clean Water and Sanitation.*

## 1) INTRODUCTION

Water is one of the most vital natural resources, essential for human survival, ecosystem stability, and socio-economic growth. In India, groundwater forms the backbone of the water supply network, catering to nearly 80% of the rural and 50% of the urban population [1]. Among different groundwater sources, borewells are widely used due to their continuous availability throughout the year. However, the quality of borewell water is often compromised by the presence of dissolved solids, heavy metals, hardness, and microbial impurities. Factors such as excessive extraction, agricultural runoff, and industrial discharge further aggravate groundwater contamination, making it unsafe for domestic consumption without suitable treatment [2]. Traditional treatment methods like chlorination, reverse osmosis, ion exchange, and coagulation are widely practiced for water purification. Although these processes effectively remove impurities, they are associated with high operational costs, complex maintenance, and the generation of secondary waste [3]. Therefore, the search for simple, economical, and sustainable purification alternatives has gained significant attention in recent years. One promising approach involves the use of bio-based adsorbents derived from agricultural and plant wastes, which are biodegradable, cost-effective, and rich in natural functional groups suitable for contaminant removal [4]. The present research focuses on the experimental evaluation of bio-based materials—Neem bark powder, Tamarind seed powder, Orange/Lemon peel powder, and Activated Charcoal—for borewell water purification. These materials were selected because of their natural abundance, high adsorption potential, and environmental compatibility. Neem (Azadirachta indica) has been recognized for its antibacterial and heavy-metal removal properties. Its bark and leaves contain cellulose, lignin, and tannins that act as active sites for adsorption of metallic ions and microbial impurities [5]. Earlier studies have demonstrated that neem bark can effectively reduce heavy metal concentrations such as zinc, cadmium, and arsenic, and improve the overall quality of contaminated water [6]. Tamarind (Tamarindus indica) seed powder is another effective bio-adsorbent with notable surface porosity and a high carbon content. Activated carbon derived from tamarind seeds has exhibited efficient adsorption capacity for metals such as Fe(III) and Pb(II) as well as organic dyes [7]. This not only enhances water quality but also promotes the reuse of agro-residues that are typically discarded as waste. Similarly, citrus fruit wastes such as orange and lemon peels are rich in pectin, cellulose, and polyphenolic compounds, which make them effective natural adsorbents. Studies have reported that activated carbon produced from orange and lemon peels can remove 90–95% of pollutants depending on the activation method and pollutant type [8, 9]. Activated charcoal, known for its extensive surface area and strong adsorption ability, has long been used in water treatment for the removal of organic and inorganic pollutants. It effectively eliminates odor, color, and toxic substances from water through physical adsorption [10]. When combined with natural bio-adsorbents such as neem bark and citrus peels, the overall

efficiency of water purification systems can be significantly enhanced, offering a cost-effective and sustainable solution. This experimental assessment aims to determine the purification efficiency of the selected materials on borewell water by analyzing parameters such as pH, turbidity, hardness, total dissolved solids (TDS), chloride concentration, and microbial count before and after treatment. The study is expected to demonstrate the comparative performance of these materials and highlight their potential as alternatives to conventional treatment technologies, especially in rural and semi-urban regions where high-cost purification systems are not feasible. Moreover, this work contributes to the concept of waste valorization, converting agricultural residues into functional adsorbents for environmental improvement.

By utilizing naturally available bio-wastes in the purification process, this research promotes sustainable water management and supports the development of affordable purification systems for communities dependent on borewell water. The findings are anticipated to provide valuable insight into designing low-cost, eco-friendly water filtration units for household and community applications.

## 2) OBJECTIVES

The specific objectives include:

1.To examine the initial quality and characteristics of borewell water samples.

2.To prepare natural adsorbents from selected bio-waste materials.

3.To assess and compare the purification efficiency of each material individually and in combination.

4.To identify the most suitable bio-material for maximum contaminant removal.

5.To suggest an affordable, eco-friendly, and sustainable purification technique for rural communities.

## 3) LITERATURE REVIEW

Access to clean water remains a major challenge in many developing regions, especially in rural communities that rely primarily on borewell sources. Conventional treatment systems such as reverse osmosis, ion exchange, and chlorination, although effective, are often costly and difficult to maintain in small-scale settings. This limitation has encouraged researchers to investigate the use of bio-based materials derived from agricultural and plant waste as sustainable and low-cost alternatives for water purification [1]. These materials are biodegradable, locally available, and rich in surface functional groups that facilitate the adsorption of contaminants. Among the various bio-adsorbents, Neem (Azadirachta indica) has attracted considerable interest due to its antimicrobial, antifungal, and adsorption capabilities. Studies have shown that neem bark and leaf powders can effectively remove heavy metals and microbial contaminants from water [2]. Neem-based adsorbents have also demonstrated potential for fluoride and turbidity reduction, making them suitable for improving borewell and groundwater quality [3]. The adsorption efficiency of neem materials depends on parameters such as pH, dosage, and contact time, which influence the binding of impurities onto the active surface sites [4]. Another promising bio-material is Tamarind (Tamarindus indica) seed powder, which serves as an excellent precursor for activated carbon. Research has revealed that chemically or thermally activated tamarind seed carbon possesses high surface area and porosity, enabling it to adsorb metals, dyes, and other pollutants efficiently [5]. Such materials not only contribute to effective water purification but also help in reusing agricultural residues that would otherwise become waste [6].

Likewise, orange and lemon peels are rich in pectin, cellulose, and lignin, which provide active functional groups capable of binding various contaminants. Activated carbon derived from citrus peel waste has been successfully used to remove dyes, organic matter, and trace metals from water, with adsorption performance aligning with Langmuir and Freundlich isotherm models [7]. These findings support the use of citrus peels as a viable natural adsorbent for water purification.

In addition, activated charcoal—either commercial or biomass-derived—remains one of the most reliable adsorbents due to its large surface area and ability to remove a broad spectrum of pollutants, including turbidity, color, odor, and dissolved organics [8].

Overall, literature indicates that combining bio-based adsorbents such as neem bark, tamarind seed, and citrus peel powders with activated charcoal can significantly improve borewell water quality. These eco-friendly and cost-effective materials show strong potential for use in rural water purification systems, aligning with sustainable development goals.

## 4) MATERIAL SELECTION

### 1. Neem Bark Powder (Azadirachta indica)

Neem bark is obtained from the trunk of the Neem tree and is rich in cellulose, lignin, and tannins, which act as natural adsorption sites for heavy metals, organic compounds, and microbial contaminants. Its inherent antibacterial properties make it effective for reducing microbial presence in water. Neem bark powder is eco-friendly, cost-effective, and easily available, making it a practical choice for rural water purification. It can be dried, ground, and sieved to produce fine powder suitable for filtration applications. Research has demonstrated its potential in removing fluoride, iron, and turbidity from groundwater.

**Fig. 1:** Neem Bark Powder (Azadirachta indica)

**2. Tamarind Seed Powder (Tamarindus indica)**

Tamarind seeds, a byproduct of tamarind fruit, are rich in proteins, polysaccharides, and carbon content, making them suitable for use as an adsorbent or for producing activated carbon. Tamarind seed powder has high porosity and contains functional groups like –OH and –COOH, which enhance the adsorption of heavy metals, dyes, and other pollutants. It is effective in reducing turbidity and contaminant levels in borewell water. Being an agricultural waste, tamarind seed powder is both environmentally friendly and cost-effective for water treatment applications.

**Fig. 2:** Tamarind Seed Powder (Tamarindus indica)

**3. Orange/Lemon Peel Powder (Citrus spp.)**

Orange and lemon peels contain pectin, cellulose, and flavonoid compounds, which make them effective natural adsorbents. Powdered or activated citrus peels can remove turbidity, organic matter, dyes, and trace metals from water. Using citrus peel powder not only improves water quality but also helps in recycling fruit waste. Studies report that activated citrus peel-based adsorbents can achieve up to 90–95% removal efficiency depending on preparation ethods.

**Fig. 3:** Orange/Lemon Peel Powder (Citrus spp.)

**4. Activated Charcoal**

Activated charcoal is a highly porous material with an extensive surface area capable of adsorbing a wide variety of organic and inorganic contaminants. It is widely used to improve water quality by reducing color, odor, turbidity, and toxic substances. When combined with bio-based powders like neem, tamarind seeds, and citrus peels, activated charcoal enhances overall purification efficiency by providing additional adsorption sites.

**Fig. 4:** Activated Charcoal

5) **METHODOLOGY**

1) **Material Sampling and Preparation:**
Each bio-adsorbent was prepared as described above and sieved to uniform size for consistency.

2) **Sample Collection:**
Borewell water samples were collected from rural domestic wells using sterilized bottles and analyzed for baseline parameter.

3) **Experimental Procedure:**

**5. 3. 1. Neem Bark powder**

**Preparation of adsorbent**

a) Collect fresh neem bark from mature Neem trees.
b) Wash the bark thoroughly with distilled water to remove dust, dirt, and other impurities.

c) Dry the cleaned bark under sunlight for 5–7 days or in an oven at 60°C until all moisture is removed.
d) Grind the dried bark into a fine powder using a mechanical grinder.
e) Sieve the powder through a 60-mesh sieve to obtain uniform particle size.
f) Store the prepared neem bark powder in airtight containers to prevent moisture absorption until use in adsorption experiments.

**Batch Adsorption experiment**

a measured amount of neem bark powder (typically 1–5 g) was added to 250 mL of borewell water in an Erlenmeyer flask. The mixture was stirred using a magnetic stirrer or shaker for contact times ranging from 30 to 120 minutes to allow sufficient interaction between the adsorbent and contaminants. After the designated contact period, the mixture was allowed to settle or filtered to separate the neem powder from the treated water. The water was then analyzed for changes in physicochemical parameters such as pH, turbidity, total dissolved solids (TDS), hardness, chlorides, and microbial content.

**Procedure**

a) Measure a specific amount of neem bark powder.
b) Add the powder to the borewell water sample in a container or flask.
c) Stir or shake the mixture for a predetermined contact time to allow adsorption of contaminants.
d) Allow the mixture to settle or filter it to separate the powder from the treated water.
e) Analyze the treated water for pH, turbidity, TDS, hardness, chlorides, and microbial content.
f) Calculate the percentage removal of contaminants using the difference between initial and final concentrations.
g) Repeat the experiment with different doses and contact times to determine the optimum conditions for maximum purification.

**5. 3. 2. Tamarind seed powder Preparation of adsorbent**

a) Collect tamarind seeds from fresh tamarind fruits.
b) Wash the seeds thoroughly with distilled water to remove pulp residues, dirt, and dust.
c) Boil the seeds for 10–15 minutes to soften and clean them further (optional step for easier drying).
d) Dry the cleaned seeds under sunlight for 2–3 days or in a hot air oven at 60°C until completely dry.
e) Grind the dried seeds into a fine powder using a mechanical grinder.
f) Sieve the powder through a 60-mesh sieve to obtain uniform particle size suitable for adsorption experiments.
g) Store the prepared tamarind seed powder in airtight containers to prevent moisture absorption until use.

**Batch adsorption experiment**

A measured amount of tamarind seed powder was added to 250 mL of borewell water and stirred for 30–120 minutes to allow adsorption of contaminants. After stirring, the mixture was settled or filtered to separate the powder from the water. The treated water was analyzed for pH, turbidity, TDS, hardness, chlorides, and microbial content. The percentage removal of contaminants was calculated using the difference between initial and final concentrations. Experiments were repeated with different doses and contact times to determine the optimum conditions for maximum purification.

**Procedure**

a) Measure a specific amount of tamarind seed powder.
b) Add the powder to the borewell water sample in a container or flask.
c) Stir or shake the mixture for a predetermined contact time to allow adsorption of contaminants.
d) Allow the mixture to settle or filter it to separate the powder from the treated water.
e) Analyze the treated water for pH, turbidity, TDS, hardness, chlorides, and microbial content.
f) Calculate the percentage removal of contaminants using the difference between initial and final concentrations.
g) Repeat the experiment with different doses and contact times to determine the optimum conditions for maximum purification.

**5. 3.3. Orange/Lemon Peel Powder Preparation of adsorbent**

a) Collect fresh orange or lemon. peels and wash thoroughly with distilled water to remove dirt and impurities.
b) Cut the peels into small pieces for faster drying.
c) Dry the peels under sunlight for 24–48 hours or in an oven at 60°C until completely dry and crisp.
d) Grind the dried peels into a fine powder using a mechanical grinder.
e) Sieve the powder through a 60-mesh sieve to obtain uniform particle size.
f) Store the prepared peel powder in airtight containers to prevent moisture absorption until use.

**Batch adsorption experiment**

A measured amount of orange or lemon peel powder was added to 250 mL of borewell water and stirred for 30–120 minutes to allow adsorption of contaminants. After stirring, the mixture was settled or filtered to separate the powder from the water. The treated water was analyzed for pH, turbidity, TDS, hardness, chlorides, and microbial content. The percentage removal of contaminants was calculated based on the difference between initial and final concentrations. Different doses and contact times were

tested to determine the optimum conditions for maximum purification.

**Procedure**

a) Measure a specific amount of orange or lemon peel powder.
b) Add the powder to the borewell water sample in a container or flask.
c) Stir or shake the mixture for a predetermined contact time to allow adsorption of contaminants.
d) Allow the mixture to settle or filter it to separate the powder from the treated water.
e) Analyze the treated water for pH, turbidity, TDS, hardness, chlorides, and microbial content.
f) Calculate the percentage removal of contaminants using the difference between initial and final concentrations.
g) Repeat the experiment with varying doses and contact times to determine the optimum purification conditions.

**5. 3. 4. Activated charcoal Preparation of adsorbent**

a) Obtain commercially available activated charcoal or prepare it from biomass sources.
b) Wash the charcoal thoroughly with distilled water to remove dust and impurities.
c) Dry the charcoal in sunlight or in an oven at 60°C until completely dry.
d) Crush and sieve the charcoal to obtain uniform granules suitable for adsorption experiments.
e) Store the activated charcoal in airtight containers to maintain its adsorption properties until use.

**Batch adsorption experiment**

A measured amount of activated charcoal was added to 250 mL of borewell water and stirred for 30–120 minutes to allow adsorption of contaminants. After stirring, the mixture was allowed to settle or was filtered to separate the charcoal from the water. The treated water was analyzed for pH, turbidity, TDS, hardness, chlorides, and microbial content. The percentage removal of contaminants was calculated using the difference between initial and final concentrations. Different doses and contact times were tested to identify the optimum conditions for maximum purification efficiency.

**Procedure**

a) Measure a specific amount of activated charcoal.
b) Add the charcoal to the borewell water sample in a container or flask.
c) Stir or shake the mixture for a predetermined contact time to allow adsorption of contaminants.
d) Allow the mixture to settle or filter it to separate the charcoal from the treated water.
e) Analyze the treated water for pH, turbidity, TDS, hardness, chlorides, and microbial content.
f) Calculate the percentage removal of contaminants using the difference between initial and final concentrations.
g) Repeat the experiment with varying doses and contact times to determine the optimum purification conditions

## 1. RESULTS AND DISCUSSION

The experimental study was conducted to evaluate the effectiveness of bio-based adsorbents in improving the quality of borewell water. Initial water analysis indicated elevated levels of turbidity, total dissolved solids (TDS), hardness, chlorides, and microbial load, which exceeded safe drinking standards.

When Neem Bark Powder was used, a significant reduction in turbidity and microbial content was observed. Turbidity decreased from the initial value to a substantially lower level, while the total bacterial count showed marked reduction, demonstrating the natural antibacterial properties of neem. The adsorption of dissolved solids and minor metals also contributed to improvement in water quality.

Tamarind Seed Powder exhibited strong adsorption capacity, particularly in reducing TDS, hardness, and chlorides. Its polysaccharides and functional groups facilitated the binding of dissolved ions, resulting in clearer and softer water. The microbial load also decreased, though not as prominently as with neem bark, suggesting its primary role in physicochemical purification.

Orange and Lemon Peel Powder showed effectiveness in reducing organic contaminants, turbidity, and odor. The high pectin and cellulose content of citrus peels provided active sites for adsorption. This material also helped slightly in reducing microbial content due to its natural flavonoids, contributing to safer water for domestic use.

Activated Charcoal demonstrated the highest overall adsorption efficiency, especially for TDS, hardness, and color removal. Its high surface area allowed rapid

Adsorption of dissolved impurities. When combined with the bio-based powders, a synergistic effect was observed, resulting in further improvement in water quality parameters.
Overall, the study indicated that each adsorbent contributed differently: neem bark mainly improved microbial safety, tamarind seed targeted dissolved ions, citrus peel reduced turbidity and organics, and activated charcoal enhanced overall physicochemical purification. The combination of these materials provided a low-cost, eco-friendly, and efficient approach for bore well water treatment.

**ADVANTAGES**

1. Eco-friendly and Sustainable: The materials used, such as neem bark, tamarind seeds, and citrus peels, are natural and biodegradable, minimizing environmental impact.

2. Cost-effective: These bio-based adsorbents are inexpensive and easily available, making them suitable for rural and low-income areas.

3. Effective Contaminant Removal: Each material targets specific contaminants—neem bark reduces microbial load, tamarind seeds remove dissolved ions, citrus peels reduce turbidity and organics, and activated charcoal improves overall physicochemical quality.

4. Easy Preparation and Use: The adsorbents can be prepared with simple drying, grinding, and sieving processes without requiring sophisticated equipment.

5. Synergistic Performance: Combining bio-based powders with activated charcoal enhances overall water purification efficiency.

6. Health and Safety: Using natural materials reduces the risk of introducing harmful chemicals into the water.

7. Waste Utilization: Agricultural by-products like tamarind seeds and citrus peels are effectively recycled, reducing solid waste.

**Limitations**

1. Limited Contaminant Range: Bio-based adsorbents may not effectively remove all types of chemical contaminants, such as heavy metals at very high concentrations.

2. Slower Adsorption Rate: Compared to some commercial water treatment methods, natural adsorbents may require longer contact times to achieve desired purification.

3. Batch Process Limitation: The study uses batch experiments, which may not directly translate to large-scale continuous water treatment systems.

4. Variation in Adsorbent Quality: Natural materials may vary
5. In composition depending on source and season, affecting consistency and efficiency.

6. Need for Pre-treatment: Some adsorbents may require drying, grinding, or chemical activation before use, which can be time-consuming.

7. Limited Shelf Life: Bio-based powders may absorb moisture or degrade over time, reducing their effectiveness if not stored properly.

## CONCLUSION

The experimental assessment of bio-based materials demonstrated that neem bark powder, tamarind seed powder, orange/lemon peel powder, and activated charcoal can effectively improve the quality of borewell water. Each adsorbent contributed differently: neem bark primarily reduced microbial contamination; tamarind seed powder targeted dissolved solids and hardness, citrus peel powder decreased turbidity and organic matter, and activated charcoal enhanced overall adsorption of impurities. The study highlighted that combining these materials further improves water purification efficiency, providing a low-cost, eco-friendly, and sustainable alternative for rural water treatment. While bio-based adsorbents have some limitations, such as slower adsorption rates and variability in natural composition, they offer a practical and environmentally safe solution for providing safer drinking water. Overall, this research confirms the potential of natural materials in developing accessible and efficient water treatment methods for communities dependent on borewell

## REFERENCES

1. D. R. Rawat, K. M. Parmar, and S. S. Thorat, "Comparative analysis of plant‑based natural coagulants for wastewater treatment," Curr. World Environ., vol. 20, no. 1, pp. 395–409, 2025.

2. Tiwari et al., "Effect of different ratio KOH treatment on neem bark in the formation of activated carbon: Adsorption characteristics study," J. Environ. Chem. Eng., 2024.

3. M. P. Patil and P. Mahajan, "Adsorption of Cu(II), Ni(II) and Co(II) on adsorbent prepared from lemon peel," Int. J. Res. Biosci. Agric. Technol., pp. 21–29, 2025.

4. "Activated carbon derived from waste orange and lemon peels for adsorption of dyes," 2022.

5. A review on recent advances of biochar from agricultural and forestry wastes, J. Environ. Chem. Eng., 2024.

6. National Research Council (US), "An Evaluation of Activated Carbon for Drinking Water Treatment," National Academies Press, 1980. Sciences.