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Performance Evaluation of a Banana Peduncle Charcoal and Sand-Aggregate Based Water Filtration System for Iron Removal

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Abstract: ***Excessive iron concentration in groundwater is a major drinking water quality problem in many rural and semi-urban areas of India. This study investigated the potential of banana peduncle charcoal as a low-cost and sustainable adsorbent for the removal of iron from groundwater. Banana peduncle charcoal was prepared through controlled carbonization, crushed, sieved into different particle sizes, and used as a filter medium in laboratory-scale filtration units along with sand and aggregate layers. Iron-contaminated groundwater was passed through different filtration configurations, and the treated water was analyzed for iron and other physical and chemical parameters at an NABL-accredited laboratory.***

The raw groundwater contained 7.17 mg/L of iron, which exceeded the permissible limits prescribed by IS 10500:2012 and WHO guidelines. Experimental results showed that the filtration unit containing banana peduncle charcoal and sand-aggregate media reduced the iron concentration to less than 0.1 mg/L. The treated water also exhibited improvements in other water quality parameters and complied with the relevant drinking water standards.

The findings demonstrate that banana peduncle charcoal, an agricultural waste material, can serve as an effective and eco-friendly adsorbent for groundwater treatment. The developed filtration system has potential as an economical household technology for providing safe drinking water in iron-affected regions.

Keywords: Groundwater treatment, Iron removal, Banana peduncle charcoal, Adsorption, Household water filter, Sustainable water treatment.

I. INTRODUCTION

Groundwater is an important source of drinking water for rural and semi-urban populations in many parts of the world. In India, particularly in West Bengal, groundwater is extensively used for domestic purposes. However, excessive iron concentration in groundwater is a common problem that affects water quality, causing undesirable colour, taste, odour, staining of household fixtures, and clogging of water supply systems. In many areas of Nadia District, West Bengal, iron concentrations in groundwater exceed the permissible limits prescribed by drinking water standards. Various methods such as aeration, oxidation, ion exchange, membrane filtration, and adsorption have been employed for iron removal from groundwater. Although effective, many of these methods require high capital investment, chemical additives, and skilled operation, limiting their applicability in rural households. Consequently, there is a growing interest in developing low-cost and environmentally sustainable treatment technologies using locally available materials. Agricultural wastes have gained considerable attention as adsorbents for water treatment due to their abundance, low cost, and renewable nature. Banana peduncle, an agricultural by-product generated after banana harvesting, is readily available in many tropical regions. When converted into charcoal, it develops a porous structure that can enhance the adsorption of contaminants from water. The present study investigates the potential of banana peduncle charcoal as a filter medium for iron removal from groundwater. Laboratory-scale filtration units containing banana peduncle charcoal, sand, and aggregate were developed and evaluated for their iron removal performance. The objective was to develop an economical, eco-friendly, and sustainable household water treatment system suitable for iron-affected regions.

II. MATERIALS AND METHODS

A. Preparation of Banana Peduncle Charcoal

The Banana peduncles were collected locally from Nadia District, West Bengal. The peduncles were washed, sun-dried, and carbonized in a closed metal container using an old pressure cooker. The resulting charcoal was crushed and sieved into different particle-size fractions for use as filter media.

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B. Development of Filtration Units

Several laboratory-scale filtration units were developed using banana peduncle charcoal, sand, and aggregate arranged in layered form. The thickness and particle size of the charcoal layer were varied to evaluate their influence on filtration performance. A control unit without charcoal was also prepared to assess the contribution of charcoal to iron removal. Coarse to medium sand**,** with the majority of particles lying between 0.30 mm and 1.18 mm was used. Following characteristics of sand were found by sieve analysis.

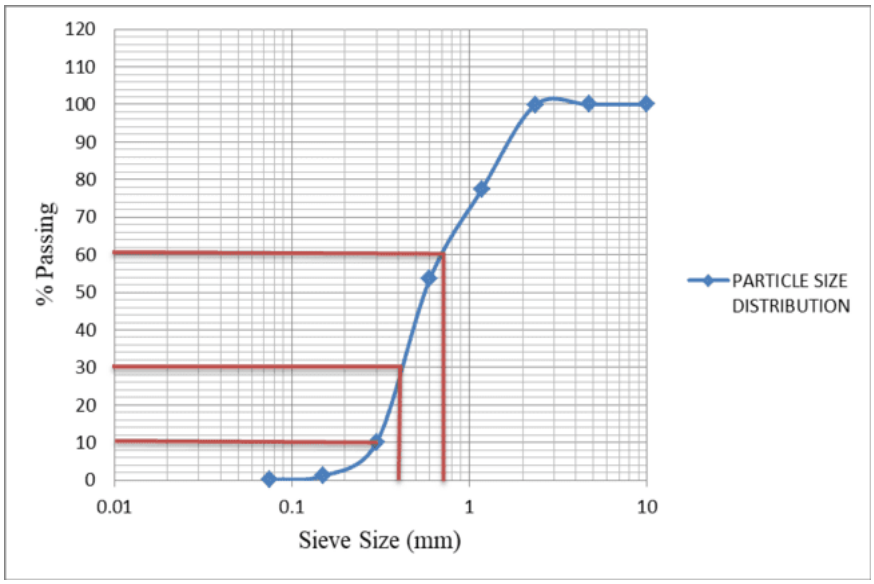


Fig. 1 Sieve analysis of sand

D_{10} = 0.3 mm
D_{30} = 0.41 mm
D_{60} = 0.72 mm

The coefficient of uniformity is:

$$C_u = \frac{D_{60}}{D_{10}} = \frac{0.72}{0.30} = 2.4$$

And the coefficient of curvature is:

$$Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}} = \frac{0.41^2}{0.3 \times 0.72} = 0.778 \approx 0.79$$

Stone aggregates of 20 mm and 10 mm size were used as supporting layers.



Fig. 2 Filtration units

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C. Water Sampling and Analysis

Groundwater samples were collected from a tube well in Nadia District. Raw and filtered water samples were analyzed for iron concentration and other physical and chemical parameters, including colour, turbidity, pH, total suspended solids (TSS), total dissolved solids (TDS), total alkalinity, total hardness, chloride, arsenic, and manganese. Analyses were conducted at the NABL-accredited Kalyani State Referral Laboratory, Public Health Engineering Directorate, West Bengal.



Fig. 3 Water sampling

D. Performance Evaluation

The effectiveness of the filtration units was evaluated by comparing water quality parameters before and after filtration. The treated water quality was assessed against IS 10500:2012 and WHO drinking water standards.

III. RESULT AND DISCUSSION

The raw groundwater contained 7.17 mg/L of iron, which exceeded both IS 10500:2012 and WHO guideline values. Filtration through banana peduncle charcoal-based units significantly reduced iron concentration. The best-performing units achieved iron concentrations below 0.1 mg/L, corresponding to iron removal efficiency greater than 98%.

The results also indicated improvements in other water quality parameters. The pH remained within the acceptable range of 6.5–8.5, while turbidity and colour were substantially reduced after filtration. Only iron concentration of Filter unit no. 3, 4 and 5 are tested. Filter Units 7 and 8 reduced turbidity to 0.36 NTU and 0.23 NTU, respectively, which were below the acceptable limit of 1 NTU. Arsenic concentrations were also reduced significantly, demonstrating the potential of banana peduncle charcoal for simultaneous removal of multiple contaminants.

The improved performance of the charcoal-containing units compared with the sand-only unit confirms the important role of adsorption in contaminant removal. The porous structure and surface functional groups of banana peduncle charcoal likely contributed to the effective adsorption of dissolved iron and other contaminants.

The **iron removal efficiency (%)** of the filtration unit was calculated using the formula:

$$\text{Removal efficiency (\%)} = \frac{C_i - C_f}{C_i} \times 100$$

Where C_i = initial iron concentration (mg/L) and C_f = final iron concentration after treatment (mg/L).

TABLE I
EXPERIMENTAL RESULT

Parameters	Filter unit numbers								
	Raw water	Unit-1	Unit-2	Unit -3	Unit -4	Unit -5	Unit-6	Unit-7	Unit-8
Colour	>50	<5	<5	-	-	-	<5	<5	<5
Odour	Agreeable	Agreeable	Agreeable	-	-	-	Agreeable	Agreeable	Agreeable
Taste	Agreeable	Agreeable	Agreeable	-	-	-	Agreeable	Agreeable	Agreeable
pH	7.38	7.36	7.22	-	-	-	7.6	7.29	7.37
Turbidity	25.55	1.68	0.48	-	-	-	1.19	0.36	0.23
Total dissolved solid	549.00	547.00	597.00	-	-	-	546.00	539.00	323.00
Total Alkalinity	404.00	384.00	482.60	-	-	-	323.00	380.00	204.00
Total Hardness	425.00	449.39	538.46	-	-	-	461.53	465.58	237.90
Chloride	38.25	41.27	47.31	-	-	-	37.25	40.27	18.58
Total Iron (mg/l)	7.17	<0.1	<0.1	<0.1	<0.1	<0.1	0.33	0.11	<0.1
Total Arsenic	0.126	0.011	0.022	-	-	-	0.050	0.026	0.029
Total Manganese	0.98	0.57	0.87	-	-	-	1.12	0.44	

IV. CONCLUSIONS

Banana peduncle charcoal was found to be an effective adsorbent for the removal of iron from groundwater. The developed filtration system reduced iron concentration from 7.17 mg/L to less than 0.1 mg/L, meeting both IS 10500:2012 and WHO drinking water standards. In addition to iron removal, the system improved turbidity, colour, and other water quality parameters. Due to its low cost, local availability, and environmental sustainability, banana peduncle charcoal has considerable potential for application in household water treatment systems in iron-affected rural areas. Further studies may focus on long-term performance, regeneration, and field-scale implementation of the technology.

V. CONCLUSIONS

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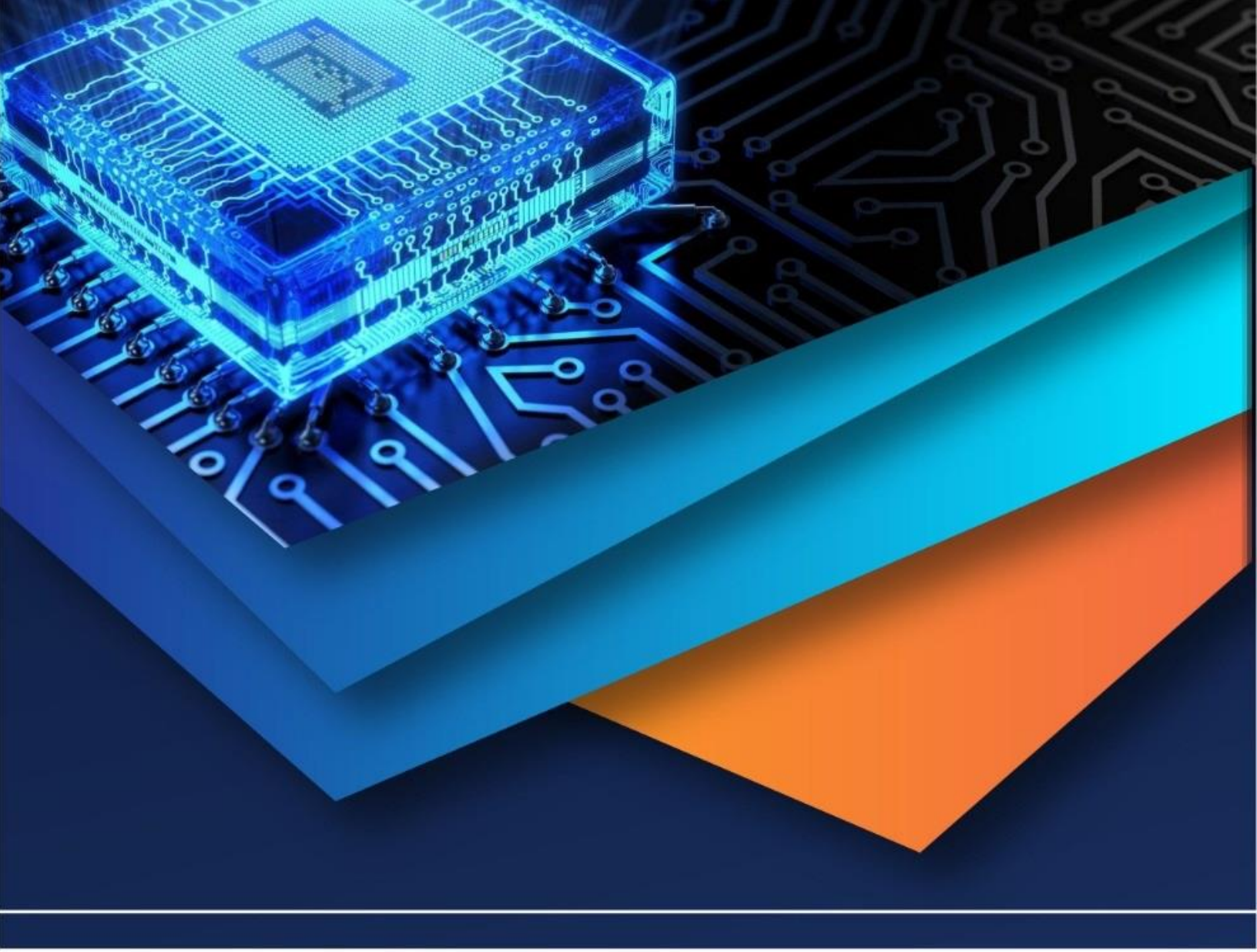
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