



# Development of Low-Cost Activated Carbon Based Filtration Media for Water Quality Improvement in Raipur Region, Chhattisgarh

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**Abstract:** Water is one of the most important natural resources for human life. Rapid urbanization, population growth, industrial activities, and climate change have increased the demand for clean water and affected its quality. In Raipur and nearby areas of Chhattisgarh, contamination of water by iron, fluoride, and other impurities has become a major concern. Therefore, there is a need to develop a simple, economical, and effective water treatment system. The present study focuses on the development of a low-cost filtration system for improving water quality in the Raipur region. Soil samples were collected from selected locations near the Kharun River, Mahanadi River, and surrounding areas. Laboratory experiments were conducted using soil columns of different depths (10 cm, 20 cm, 30 cm, 40 cm and 50 cm) to study infiltration characteristics and identify the most suitable soil column depth. Activated carbon was prepared from locally available materials such as rice husk, sugarcane bagasse, and wood charcoal. These materials, along with zeolite, were used as

filter media in combination with soil columns. Water samples containing high concentrations of iron and fluoride were treated through the developed filtration model to evaluate their removal efficiency. The results showed that the 50 cm soil column provided the best filtration performance. Rice husk activated carbon, wood charcoal, and zeolite were found to be highly effective in removing iron and fluoride from water. The filtration system achieved significant water quality improvement while maintaining a satisfactory rate of flow. The system requires very little maintenance and uses low-cost, locally available materials. The developed filtration technology can be used for riverbank filtration, groundwater recharge, rain water harvesting systems, and household water treatment in Raipur and other parts of



Chhattisgarh. It offers a sustainable and affordable solution for providing safe drinking water to rural and urban communities.

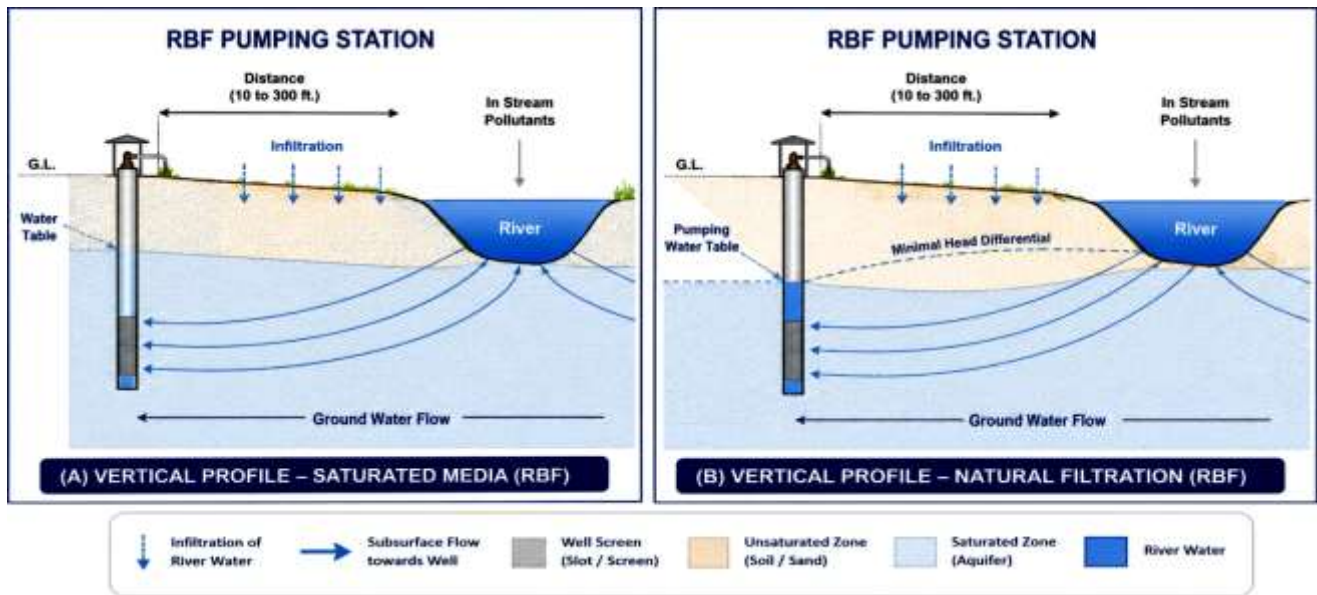
**Keywords:** *Water Quality, Raipur, Chhattisgarh, Activated Carbon, Rice Husk, Sugarcane Bagasse, Zeolite, Iron Removal, Fluoride Removal, Low-Cost Filtration System.*

## 1. Introduction

### 1.1 General

Water is one of the most essential natural resources for sustaining life and supporting economic development. However, the world is facing significant challenges in meeting the increasing demand for safe and clean water due to rapid population growth, urbanization, industrialization, climate change, and recurring drought conditions. Although water covers a large portion of the Earth's surface, only a small percentage is available as fresh water suitable for human consumption. Therefore, the protection and efficient management of available water resources have become a global priority. In Raipur, the capital city of Chhattisgarh, rapid urban expansion and industrial development have increased the pressure on both surface water and groundwater resources. The Kharun River, Mahanadi River, and groundwater aquifers are important sources of water supply for domestic, agricultural, and industrial purposes. However, increasing population, improper waste disposal, agricultural runoff, and industrial activities have adversely affected water quality in many areas. Contamination by iron, fluoride, suspended solids, and other pollutants has become a growing concern for public health and environmental sustainability.

Conventional water treatment methods often require expensive chemicals and sophisticated infrastructure, making them difficult to implement in rural and economically weaker regions. Moreover, some chemical treatment processes may generate secondary pollutants and increase operational costs. Therefore, there is a growing need for low-cost, environmentally friendly, and locally available treatment alternatives. Natural filtration materials and agricultural waste products such as rice husk, sugarcane bagasse, and wood charcoal have shown considerable potential as economical adsorbents for water purification. These materials are easily available in Chhattisgarh and can be converted into activated carbon for removing contaminants from water. The use of such low-cost filter media can significantly reduce treatment costs while improving water quality. Considering the increasing water quality issues in Raipur and surrounding areas, the present study focuses on the development of an efficient and affordable filtration system using locally available materials for the removal of iron and fluoride from water. The study also investigates the infiltration characteristics of different soil types and their suitability for riverbank filtration and groundwater recharge applications. Even well-protected water sources and properly managed water supply systems do not always guarantee safe drinking water at the household level.



**Figure 1.1: (A) Vertical Profiles near the Saturated Zone of the River Banks, (B) Water Purification through Natural Media**

## 1.2 Research Objectives

1. To determine the infiltration characteristics of different soil types collected from selected locations in Raipur region.
2. To evaluate the physical and chemical properties of riverbank soils and their suitability for riverbank filtration.
3. To prepare activated carbon using locally available agricultural waste materials such as rice husk and sugarcane bagasse.
4. To investigate the removal efficiency of iron and fluoride from water using activated carbon, zeolite, and soil columns.
5. To evaluate the effect of infiltration rate and filter media arrangement on water quality improvement.
6. To identify a low-cost and sustainable filtration system suitable for water treatment in Raipur and surrounding regions.
7. To perform cost-benefit analysis and assess the applicability of the developed filtration system for rural and urban communities.

## 2 Literature Review

Many researchers over the globe are finding out on the water quality capabilities and performance using different techniques. Some of these recent studies are mentioned below:

Among the earlier investigators, Catherine (1988) studied the management of biological iron removal from drinking water using oxidation-reduction potential. During this study a pilot plant was used for treating raw water with pH 5.7 for biological removal of iron to produce drinking water. Here oxidation-reduction potential was used as a tool for evaluation and determination of relationship with dissolved oxygen and residual iron concentration within the infiltrate by employing a biological filter.



**Hasan (1990)** studied the contact aeration for iron removal methodology. The iron removal method utilized the catalytic impact of ferric iron. Again in this experiment it had been theoretically demonstrated that by keeping high concentration of ferric iron, the volume of the aeration tank are often significantly reduced and it had been according to the oxygenation rate equation. Ferric iron is very much effective in decreasing the reactor volumes at lower pH values. It's projected to recycle the ferric sludge to maintain the high ferric iron concentrations within the reactor.

**William, et al. (1992)** studied the impact of dissolved organic carbon on the removal of iron throughout water treatment. He used the iron removal method by oxidation and coagulation method. Humic and fulvic acids, tannic acid and oxalic acid were calculable within the organic content. Potassium permanganate, chlorine dioxide and free chlorine were used as oxidizing agent.

**Dong, et al. (1992)** conducted experiments on Surface coatings were collected on glass slides within the oxic surface waters of Cayuga Lake and Hydroxylamine hydrochloride was used to selectively remove Mn oxides, sodium dithionite was used to remove Mn and Fe oxides, and 10% oxalic acid was used to remove metal oxides and organic materials. Were went to appraise the relative contributions of Fe, Mn adsorption by the surface coating materials. The estimated Pb distribution between surface coating components with that previously predicted by an additive adsorption model based on Pb adsorption isotherms for laboratory surrogates for Mn, Fe and Al oxides and defined biological elements.

**Wang, et al. (2003)** studied the removal of heavy metal ions from liquid solutions using various adsorbents with minimal cost. He used various low cost adsorbents like Fe<sub>2</sub>O<sub>3</sub>, Fe<sub>3</sub>O<sub>4</sub>, FeS, steel wool, Magnesium pallets, Copper pallets, Zinc pallets, Aluminum pallets, Iron pallets, coal, GAC for removal of heavy metal ions like cobalt and zinc from ground water.

### 3. Data Collection

There is no standard procedure for obtaining soil samples, as the sampling method depends on the objectives of the study, the required sampling depth, and the type of sample needed (disturbed or undisturbed). In the present study, soil samples were collected using a hand auger, extension rods, a T-handle, and a thin-wall tube sampler. The auger was used to bore a hole up to the desired depth, after which the auger tip was replaced with a tube core sampler. The sampler was lowered into the borehole and pushed into the soil to collect representative samples. The collected soil cores were carefully withdrawn, labeled, and transported to the laboratory for further analysis.

The study was conducted in and around Raipur, Chhattisgarh, where groundwater and river water are important sources of water supply. Soil samples were collected from selected locations along the Kharun River, Mahanadi River (near Arang), and nearby groundwater recharge zones. These sites were selected to represent different riverbank and alluvial soil conditions commonly found in the Raipur region. The collected samples were used to determine the physical and chemical properties of soils and to evaluate their suitability for riverbank filtration and water quality improvement. The



sampling locations were selected based on accessibility, hydrogeological conditions, and their potential influence on groundwater recharge and filtration processes. The locations of the selected sampling sites are shown in Figure 3.1.

### Proposed Sampling Locations

Sampling Site	Location	Latitude (N)	Longitude (E)
S1	Kharun River, Raipur	21.2514°	81.6296°
S2	Mahadev Ghat, Raipur	21.2200°	81.6500°
S3	Mahanadi River, Arang	21.1960°	81.9690°
S4	Sejbahar Area, Raipur	21.1800°	81.7000°

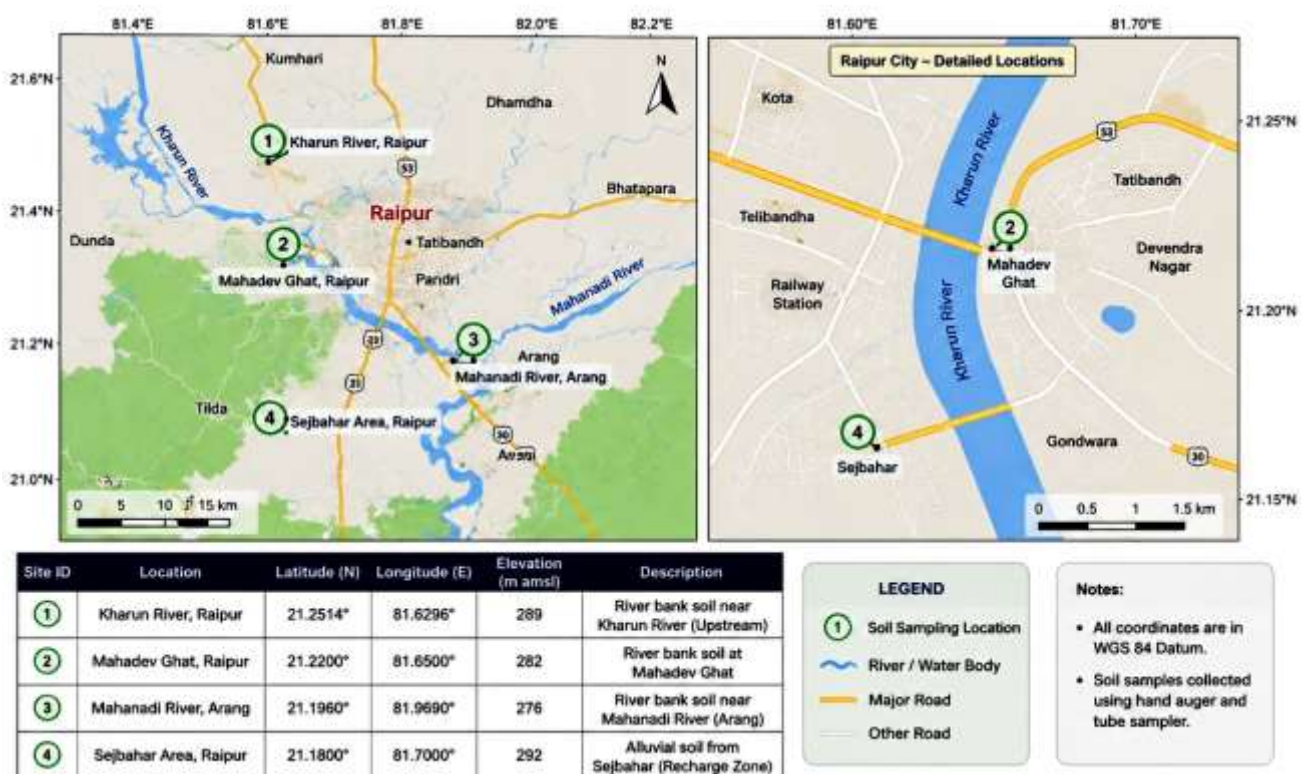


Figure 3.1: Map Showing Four Soil Sampling Sites at River Banks

## 4. Methodology

### 4.1 General

Various experiments were carried out to study the characteristics of soil samples collected from selected locations along the Kharun River, Mahanadi River (near Arang), Mahadev Ghat, and Sejbahar area of Raipur, Chhattisgarh. These locations were chosen to represent different riverbank and alluvial soil conditions commonly found in the Raipur region. Initially, the collected soil samples were subjected to detailed laboratory investigations to determine their physical properties and suitability for riverbank filtration and water quality improvement studies. The following physical parameters were analyzed through experimental testing:



- ❖ Test for Grain Size Distribution
- ❖ Test for Liquid Limit
- ❖ Test for Plastic Limit
- ❖ Test for Shrinkage Limit
- ❖ Test for Specific Gravity
- ❖ Test for Moisture Content

Thereafter, the following chemical analysis was done.

- ❖ Test for Alkalinity i.e. pH Test
- ❖ Test for Iron and Fluoride Content

**Table 4.1: Determining Peaks for Mineral**

Steps	Mg-Sat. Air-Dried	Mg-Sat., Glycerol Solvated	K-Sat. Air-Dried
1	Mgcl <sub>2</sub>	Mgcl <sub>2</sub>	Kcl
2	Mgcl <sub>2</sub>	Mgcl <sub>2</sub>	Kcl
3	Mgcl <sub>2</sub>	Mgcl <sub>2</sub>	Kcl
4	Mgcl <sub>2</sub>	Mgoac	Kcl
5	Ethanol	Ethanol	50% Ethanol
6	Ethanol	Ethanol	95% Ethanol
7	Ethanol	Ethanol	95% Ethanol
8	Ethanol	1% Glycerol- Ethanol	Triple Distilled- Water

## 5. Analysis of Results

### 5.1 Grain Size Distribution

The grain size distribution of soil samples was characterized at four selected riverbank and recharge-zone locations in the Raipur region, namely Kharun River (Raipur), Mahadev Ghat, Mahanadi River (Arang) and Sejbahar Area. Representative soil samples were collected from these locations following standard sampling procedures to ensure reliability and consistency of the experimental results.

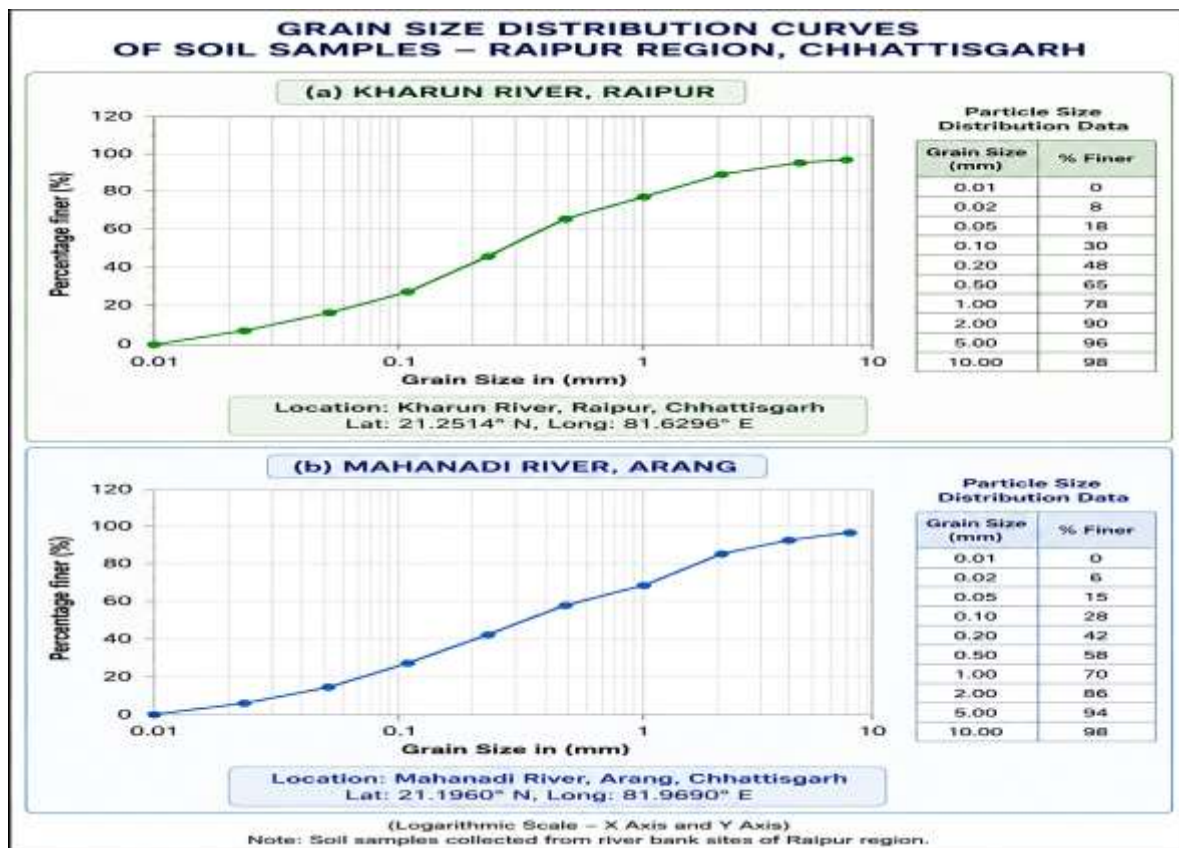
Geotechnical engineers generally classify soils as well-graded or poorly graded based on the particle size distribution characteristics according to ASTM D2487 (Unified Soil Classification System, USCS). This classification is determined using two important parameters: the coefficient of uniformity ( $C_u$ ) and the coefficient of curvature ( $C_c$ ), which are expressed as:

$$C_u = D_{60}/D_{10} \text{ and } C_c = (D_{30})^2 / (D_{60} \times D_{10})$$

Where  $D_{60}$ ,  $D_{30}$  and  $D_{10}$  refer to particle-size diameters corresponding to 60, 30 and 10% passing respectively. If sand contains less than 12% fines and if  $C_u$  is  $\geq 6$  and  $1 \leq C_c \leq 3$ , then it is classified as well graded. If  $C_u < 6$  or  $C_c < 1$  or  $C_c > 3$ , then it is classified as poorly graded (see Peck et al. 1974, p. 9 regarding gap-graded sand). The results obtained in the present work are shown in Figure 5.1. The relevant geo technical parameters are presented in figure 5.1, where it can be seen that the average



mean particle size,  $D_{50}$ , is ranging between 0.1 mm to 0.6 mm. Thus, these soils are slightly on the sandy silt side of course, the USCS does not actually distinguish whether sandy silt sand is poorly graded or well-graded. However, strictly abiding by the Unified Soil Classification System (USCS) would not convey the broad range of particle sizes. However, the average coefficient of uniformity,  $C_u$ , greater than 6 and the average coefficient of curvature,  $C_c$ , between 1 and 3, has been described as well-graded. One of the reasons that geotechnical engineers prefer to use the phrase “well- graded” instead of “poorly sorted” is that the former connotes the idea that such soil compacts well, producing a good, dense structural fill. But as the uniformity coefficient,  $C_u = D_{60}/D_{10}$  increases, it can result differently. In particular, it has been known for a long time that soils having a  $C_u$  less than 10 are self-filtering with respect to a hydraulic gradient, but soils having a  $C_u$  more than 20 are likely to be internally erodible and, hence, unstable (United States Bureau of Reclamation 1960; Kovacs 1981; and Skempton and Brogan 1994).



**Figure 5.1: Grain Size Distribution of Soil Samples**

As shown in Figure 5.2, the soils collected from Kharun River, Mahadev Ghat, Mahanadi River (Arang) and Sejbahar Area exhibited different particle size distribution characteristics. The coefficient of uniformity ( $C_u$ ) values were found to be 8.0, 6.5, 12.5 and 4.2, respectively, whereas the coefficient of curvature ( $C_c$ ) values were observed as 1.85, 1.40, 2.35, and 1.10, respectively.

According to the Unified Soil Classification System (USCS), soils having a coefficient of uniformity ( $C_u$ ) greater than 6 and a coefficient of curvature ( $C_c$ ) between 1 and 3 are generally classified as



well-graded soils. Based on these criteria, the soils collected from Kharun River, Mahadev Ghat and Mahanadi River locations were found to be well-graded. However, the soil collected from the Sejbahar area exhibited a relatively lower coefficient of uniformity, indicating comparatively poor grading characteristics.

The grain size distribution curves indicate that the Mahanadi River soil possesses a broader range of particle sizes, which contributes to better packing characteristics and improved filtration performance. Such well-graded soils generally provide enhanced infiltration capacity and greater resistance against internal erosion. In contrast, the Sejbahar soil contains a relatively narrow particle size distribution, resulting in lower hydraulic conductivity and reduced filtration efficiency.

A good fit of the grain size distribution curve is essential for predicting the soil-water characteristic curve and evaluating infiltration behavior. The presence of both coarse and fine particles significantly influences water retention and permeability characteristics. Excessive fine particles may reduce permeability, whereas the absence of fine fractions may result in rapid drainage and reduced filtration effectiveness.

The analysis indicates that soils collected from the Kharun River and Mahanadi River locations are particularly suitable for riverbank filtration applications due to their favorable grading characteristics and infiltration properties. These soils can effectively support groundwater recharge and natural filtration processes. The results also demonstrate that soil texture and particle size distribution play a crucial role in determining the performance of filtration systems developed for water quality improvement in the Raipur region.

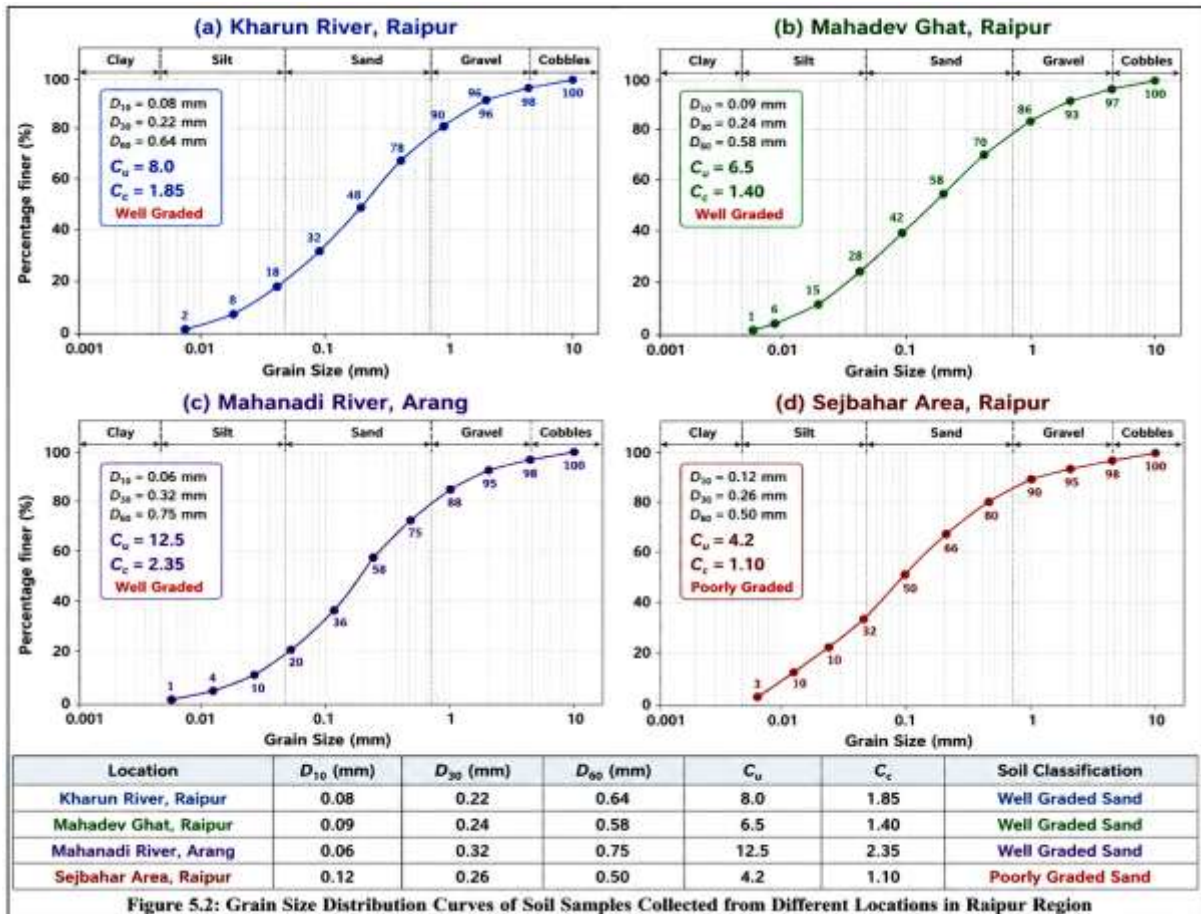


Figure 5.2: Grain Size Distribution Curves of Soil Samples Collected from Different Locations in Raipur Region

Figure 5.2: Coefficient of Uniformity and Coefficient of Curvature Plots

## 5.2 Liquid Limit Test

The Liquid Limit (LL) is the moisture content at which a soil changes from a plastic state to a liquid state. Liquid limit tests were conducted on soil samples collected from Kharun River, Mahadev Ghat, Mahanadi River (Arang) and Sejbahar Area, Raipur using the Casagrande apparatus. The number of blows ranged from 15 to 35, and the results are presented in Figure 5.3. The average liquid limit values were found to be 23.8%, 25.4%, 24.9% and 27.6%, respectively. These values indicate low to medium plasticity and suggest that the soils are suitable for infiltration and filtration applications. The test results were further used to determine the Flow Index (If), as shown in Figure 5.3.

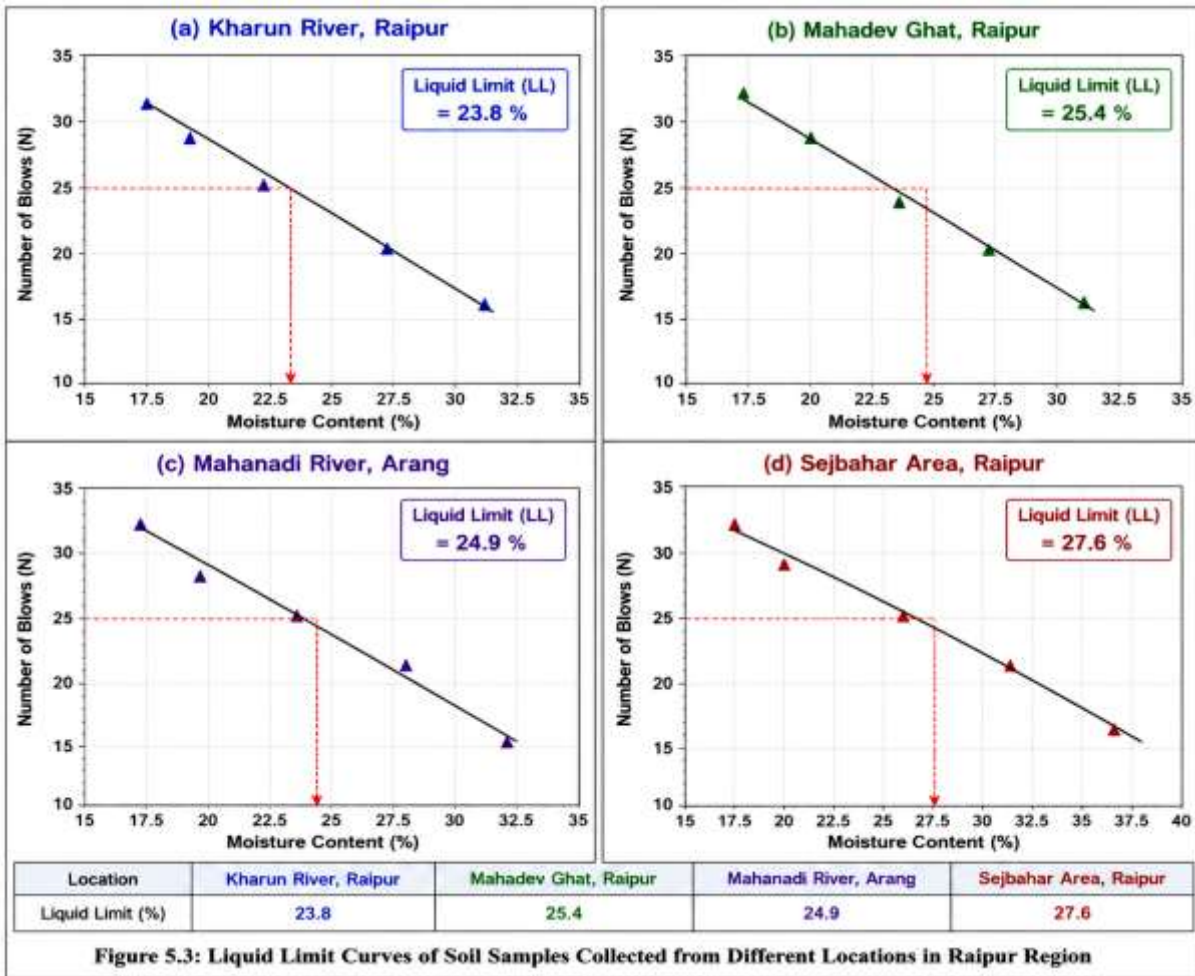


Figure 5.3: Liquid Limit Curves of Soil Samples Collected from Different Locations in Raipur Region

Figure 5.3: Liquid Limits of Soil Samples

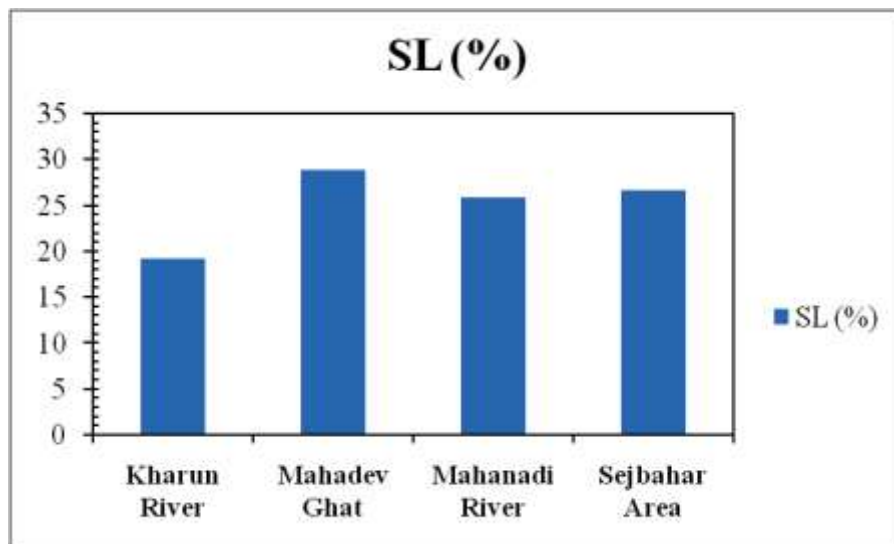


Figure 5.4: Shrinkage Limit of All the Soil Samples

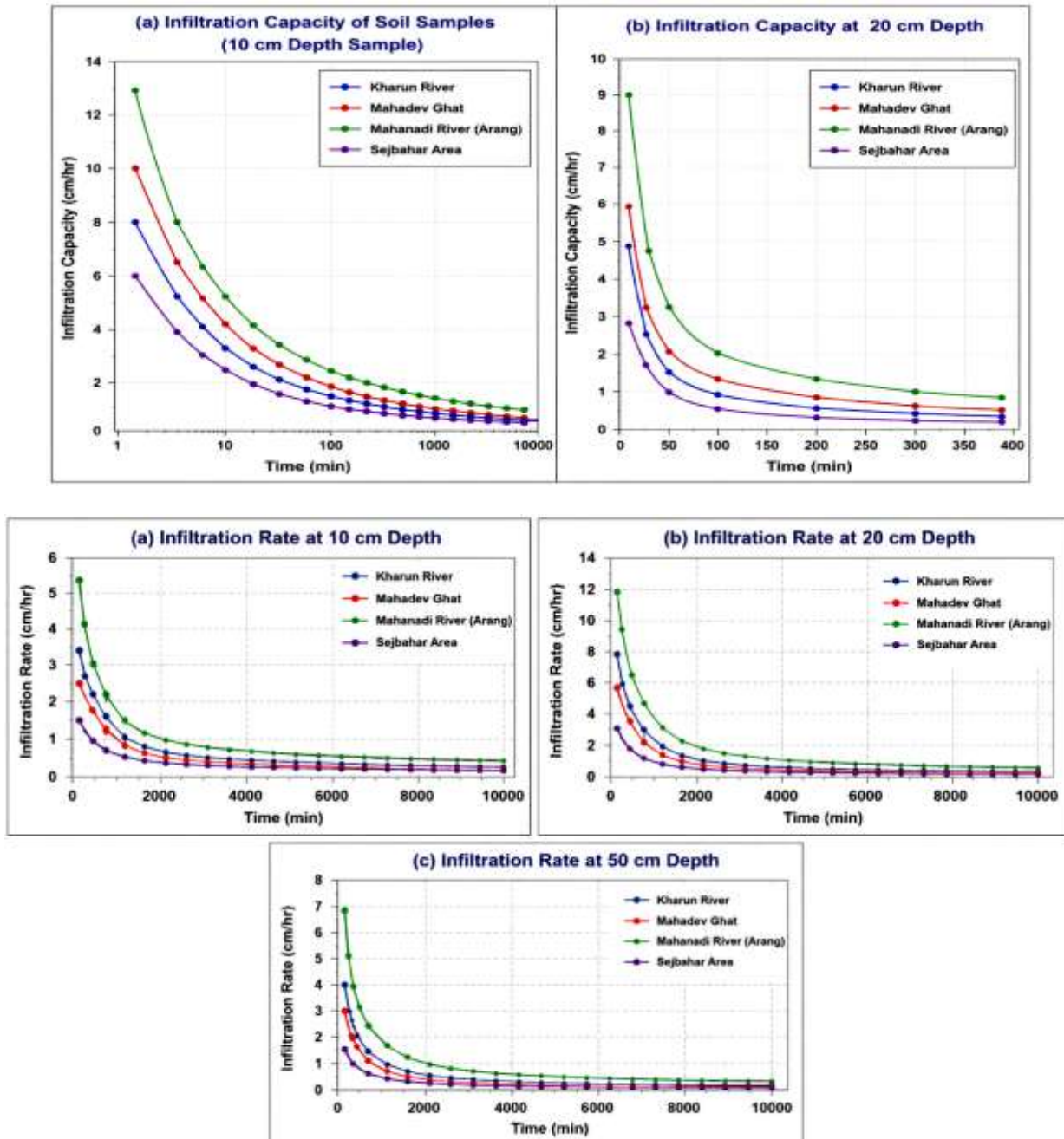


**Table 5.1 Mineral Composition of Soil Samples for Four Selected Locations from Study Area**

Location	Compound Name	Chemical Formula
Kharun River	Calcite,	$\text{CaCO}_3$
	Smectites,	$\text{A } 0.3\text{D } 3[\text{T4O10}] \text{Z}_2 \cdot \text{H}_2\text{O}$
	Vermiculites	$\text{Mg}_{1.8}\text{Fe}_{2+0.9}\text{Al}_{4.3}\text{SiO}_{10}(\text{OH})_2 \cdot 4(\text{H}_2\text{O})$
Mahadev Ghat	Kaolinite,	$\text{Al}_2 \text{Si}_2 \text{O}_5 (\text{OH})_4$
	Dolomite,	$(\text{Ca Mg}) (\text{CO}_3)_2$
	Chlorites	$(\text{Mg,Fe})_3(\text{Si,Al})_4\text{O}_{10}$
Mahanadi River	Smectites	$\text{A } 0.3\text{D } 3[\text{T4O10}] \text{Z}_2 \cdot n \text{H}_2\text{O}$
	Aragonite,	$\text{CaCO}_3$
	Chlorites	$(\text{Mg,Fe})_3(\text{Si,Al})_4\text{O}_{10}$
Sejbahar Area	Calcite,	$\text{CaCO}_3$
	Kaolinite,	$\text{Al}_2 \text{Si}_2 \text{O}_5 (\text{OH})_4$
	Vermiculites	$\text{Mg}_{1.8}\text{Fe}_{2+0.9}\text{Al}_{4.3}\text{SiO}_{10}(\text{OH})_2 \cdot 4(\text{H}_2\text{O})$

**Table 5.2 Physical Properties of Mahanadi River (Arang)**

Physical Parameters	Values	Physical Parameters	Values
Colour	Light Red	Shape	Rounded/Sub-Rounded
Silt & Clay (%)	87	Uniformity Co-Efficient, $C_u$	3.50
Fine Sand (%)	13	Co-Efficient Of Curvature, $C_c$	2.03
Medium Sand (%)	0	Specific Gravity(G)	2.54
Coarse Sand (%)	0	Plasticity Index	Non-Plastic



**Figure 5.5: Infiltration Rate of All the Soil Samples at Different Depths**

It was observed that the rate of water flow under natural conditions was approximately 0.20 litre per hour for the soil sample collected from the Kharun River, Raipur, indicating relatively low infiltration under gravity flow conditions. However, with an increase in the pressure head, the flow rate increased significantly due to the enhancement of hydraulic gradient and infiltration capacity. Therefore, the Kharun River soil was selected, along with other filter media, for evaluating water quality improvement and contaminant removal efficiency. The best-fit equation obtained for the Kharun River soil can be expressed as:

**Table 5.3 Rate of Infiltration at Different Layers**

Layers	Filter Materials				
	Sediment	Sugar Cane	Rice Husk	Zeolite	Wood Coal
Upper	-	1.51	1.17	1.61	1.25
Center	-	1.03	1.5	1.73	2
Bottom	-	1.9	1.31	2.03	1.26

We observed Rate of filtration combination of both different filter materials with different location after that we see from above combination the quality improvement.

**Table 5.4 Water Quality Improvement at Different Layers**

Layers	Filter Materials				
	Sediment	Sugar Cane	Rice Husk	Zeolite	Wood Coal
Upper	-	4.096	3.049	1.01	1
Center	-	0.823	0.329	0.023	0.13
Bottom	-	3.28	2.72	0.096	0.91

### 5.15.1 Cost Analysis

Finally cost estimation is play a crucial role in this work to named as low cost. Before implementing the work, it is highly necessary, whether it is economical or not. Hence, we provided a chart for all the filter materials used for experimentation is given in the table.

Material	Quantity (Gram)	Cost
Zeolite	39	4.18
Activated Carbon	44.5	8.9
Sugarcane Baggase	20.4	2.6
Rice Husk	20.9	5.8
Wood Coal	33.2	3.32

## 6.1 Conclusion

1. The study of physical properties of soil is essential for understanding infiltration behavior and assessing the suitability of soils for riverbank filtration and groundwater recharge applications.
2. The results of grain size distribution, coefficient of uniformity (Cu), coefficient of curvature (Cc), liquid limit, plastic limit, shrinkage limit, specific gravity, and infiltration tests indicated that the soils collected from Kharun River, Mahadev Ghat, Mahanadi River (Arang), and Sejbahar Area are suitable for filtration and water quality improvement studies.
3. Infiltration tests conducted on soil columns of different depths (10 cm, 20 cm, 30 cm, 40 cm, and 50 cm) showed that infiltration rate decreases with time and gradually approaches a constant



value. Among the tested soils, the Mahanadi River (Arang) soil exhibited the best infiltration characteristics.

4. The 50 cm soil column provided the most effective results and was selected for water quality improvement studies involving iron and fluoride removal.

5. Soil filtration alone achieved approximately 20-30% removal of iron, demonstrating the natural purification potential of riverbank soils.

6. Zeolite proved to be highly effective for iron removal, achieving nearly 100% removal efficiency under optimum conditions.

7. Low-cost filter materials such as Sugarcane Bagasse, Rice Husk, and Wood Charcoal were successfully used for water quality improvement. The particle size of the filter media ranged between 425  $\mu\text{m}$  and 600  $\mu\text{m}$ .

8. All three filter materials achieved excellent iron removal performance, with the highest efficiency observed when the filter media was placed in the middle layer of the soil column.

9. Rice husk activated carbon and wood charcoal showed particularly high adsorption capacity, while sugarcane bagasse provided effective treatment at the lowest cost.

10. The developed filtration system is simple, economical, environmentally friendly, and suitable for improving water quality in rural and urban areas of Raipur and surrounding regions.

## 6.2 Future Scope of Study

The present work leaves a wide scope for future investigators to explore many other aspects of Water Quality analysis. Efforts are needed to promote other parameter estimation. The traditional water treatment system under economic conditions may be suitably replaced by low cost filter using materials like activated carbon, made in laboratory. On the basis of the Different surface area have being 0.1-0.01 micron size Filter water pass through it.

There is an urgent need to focus on alternative to developed proper filter materials having sediment silt & clay pre combination along this activated carbon to increase rate of flow. This leads to the need for extending domestic water facilities.

To design potable water purifiers, community level water purifier at low cost base on locality available materials.

To patent the develop low cost filter, Design of potable filter & community able filter, Home made use, also provide UV use for kill bacterial and also use image process for identification of metal iron present in water.



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