NOVEL TECHNIQUE TO REMOVE FLUORIDE CONTENT USING BIOCHAR

Project Reference No.: *47S_BE_3300*

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Keywords

- Fluoride removal
- Biochar
- Water treatment
- Adsorption
- Contaminant removal
- Environmental remediation
- Drinking water
- Sustainable technology

Introduction

Background

Water purity is a critical and often challenging issue in India, a country with a rapidly growing population, industrialization, and diverse geographical and climatic conditions. Access to safe and clean drinking water is a fundamental human right and essential for public health, yet a significant portion of the Indian population faces water quality and purity challenges. In India, several techniques are used to remove fluoride content from drinking water sources, especially inareas where high fluoride levels pose a health risk. These techniques aim to provide access to safe and fluoride-free drinking water to affected communities. Some common techniques used in India for fluoride removal include: Activated Alumina Defluoridation, Bone Char Defluoridation, Electrocoagulation.

It's important to note that while fluoride is beneficial for dental health at appropriate levels, excessive fluoride intake can lead to dental fluorosis and other health issues. Therefore, monitoringand controlling fluoride content in drinking water and other sources is essential to ensure public health and safety. Local authorities and health organizations often establish guidelines andregulations to manage fluoride levels in different contexts to maintain a balance between the benefits and risks associated with fluoride exposure.

Defluoridation of water using biochar is vital for protecting public health, promoting sustainability,and empowering communities in areas affected by excessive fluoride levels in drinking water. Its environmental friendliness, cost-effectiveness, and scalability make it a compelling and practical solution to mitigate the adverse health effects associated with fluoride contamination.

Effects of Excess Fluorides in Drinking Water

The following are some of the possible sources of excessive fluoride exposure: fluoridated public water; high fluoride concentrations in naturally occurring fresh water; fluoridated toothpaste or mouthwash; untested bottled water; and improper usage of fluoride supplements in particular foods. Mild dental fluorosis can be brought on by exposure to high fluoride concentrations when teeth areorming in childhood. The enamel of the tooth will have microscopic white streaks or flecks. The discoloration may be apparent, but the health of the teeth is unaffected.

- Dental Fluorosis: This is a common condition caused by overexposure to fluoride during the development of teeth. It manifests as white streaks or spots on the teeth and, in severe cases, can lead to brown discoloration and pitting of the enamel, affecting dental aestheticsand potentially causing tooth sensitivity.

- Skeletal Fluorosis: Prolonged exposure to high levels of fluoride can cause skeletal fluorosis, a bone disease characterized by pain and stiffness in the joints, calcification of ligaments, and bone deformities. This condition can significantly impair mobility and quality of life.
- Thyroid Dysfunction: Excessive fluoride intake has been linked to thyroid problems,including hypothyroidism and hyperparathyroidism. These conditions can disrupt the normal function of the thyroid gland, leading to hormonal imbalances and related health issues.
- Neurological Effects: Some studies suggest that high fluoride levels may have neurotoxic effects, particularly in children. Excessive fluoride intake during early development has been associated with lower IQ scores and cognitive impairment.
- Kidney Damage: Long-term exposure to high fluoride levels can damage the kidneys and impair their function. This can lead to various renal problems, including kidney stones and chronic kidney disease.
- Gastrointestinal Distress: Acute fluoride poisoning, usually from ingesting large amounts offluoride-containing compounds, can cause gastrointestinal symptoms such as nausea, vomiting, abdominal pain, and diarrhea.
- Cardiovascular Effects: There is some evidence to suggest that high fluoride exposure may be associated with an increased risk of cardiovascular disease, although more research is needed to confirm this link.

Table 1.1: Standards for Drinking Water

Parameter	**Indian Standards (IS 10500-2012)**		**ICMR**		**WHO**	
	(P)	(E)	(P)	(E)	(P)	(E)
Physical:						
Colour (units)	10	50	5	25	5	50
Taste and odor	Unobjectionable		Nothing disagreeable		Unobjectionable	
Turbidity (NTU)	05	10	5	25	5	25
Chemical:						
pH	6.5- 8.5	No relaxation	7.0 - 8.5	6.5 - 9.2	7.0 - 8.5	6.5 - 9.2
Total solids	--	--	--	--	500	1500
Total Dissolved solids	500	2000				
Total hardness	200	600	300	600	--	--
Alkalinity	200	600				
Calcium	75	200	75	200	75	200
Magnesium	30	100	50	150	50	150
Copper	0.05	1.5	1.0	3.0	1.0	1.5
Iron	0.3	1.0	0.3	1.0	0.3	1.0
Manganese	0.1	0.5	0.1	0.5	0.1	0.5
Chlorides	250	1000	250	1000	200	600
Sulphates	200	400	200	400	200	400
Nitrate	45	--	20	50	--	50-100
Fluoride	1	1.5	1.0	2.0	0.5	1.0-1.5
Phenol	0.001	0.002	0.001	0.002	0.001	0.002
Toxic:						
Arsenic	0.05	--	--	0.2	--	0.2
Cadmium	0.05	--	--	0.05	--	0.05
Cyanide	0.05	--	--	0.01	--	0.01
Lead	0.1	--	--	0.1	--	0.1
Selenium	0.01	--	--	0.05	--	0.01
Zinc	5.0	10.0	--	--	--	--
Mercury	0.01	--	--	--	--	--
Bacteriological	1 coliform per 100ml		1 coliform per 100ml		1 coliform per 100ml	
Radioactivity:						
Alpha emitters(µc/ml)	10^{-3}	--	--	10^{-3}	--	10^{-3}
Beta emitters(µc/ml)	10^{-7}	--	--	10^{-8}	--	10^{-8}

Note: All units except otherwise mentioned and pH, specific conductance and radioactivity are in mg/L.

The above table provides the standards for various parameters in drinking water set by Indian standards (IS 10500-2012), the Indian Council of Medical Research (ICMR), and the World Health Organization (WHO). These standards are essential for ensuring the quality and safety of drinking water.

Status of India's Fluoride concentration in Drinking Water

This map displays the fluoride level distribution in India, showing how fluoride concentrations are distributed across different regions of the country. The darker and more concentrated areas on the map indicate higher fluoride levels, while lighter areas represent lower fluoride levels. Fluoride levels in drinking water are an important consideration for public health, as both deficiency and excess of fluoride can have significant health implications. While fluoride is essential for dental health in appropriate amounts, excessive fluoride intake can lead to dental and skeletal fluorosis, among other health issues.

The map helps us understand the geographic distribution of fluoride levels in India and identify regions where fluoride concentration may be a concern. For example, you might notice that certain regions, particularly those with geological characteristics conducive to high fluoride content in groundwater, exhibit darker shades indicating higher fluoride levels. Conversely, regions with lighter shades may have lower fluoride levels and may not face as significant health risks associated with fluoride intake. Understanding the distribution of fluoride levels across different states and regions can inform public health initiatives aimed at mitigating the risks associated with fluoride exposure. This includes measures such as water fluoridation, monitoring of fluoride levels in drinking water sources, and public education campaigns on safe fluoride intake practices. By analysing fluoride level distribution through this map, policymakers and health authorities can better address the challenges of fluorosis prevention and ensure access to safe drinking water for all populations across India.

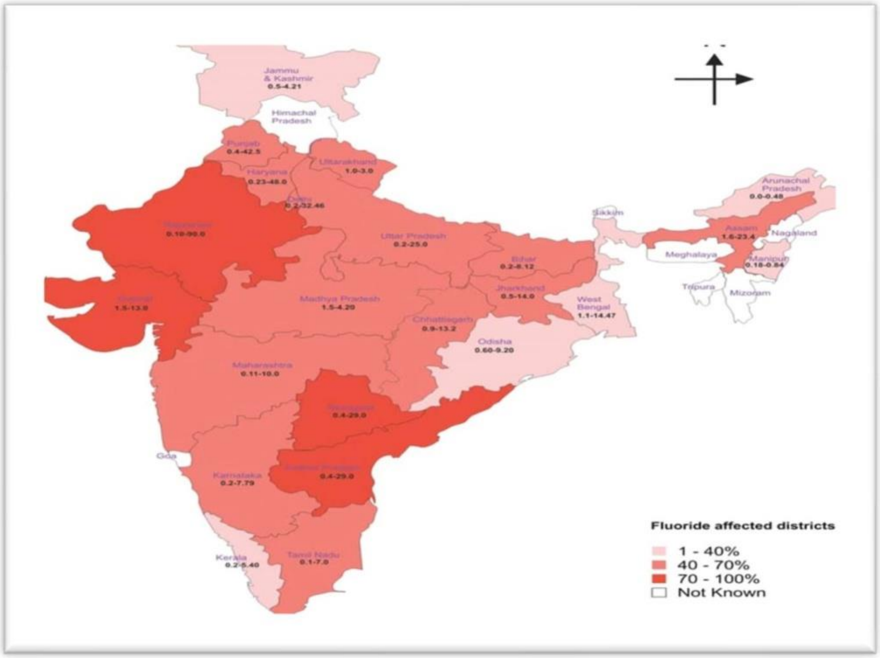


Fig: 1.1 Variation of fluoride concentration in India

Source: Map-of-India-showing-fluoride-in-ppm-distribution-in-states-and-union-territories-This.gif(746×846) (researchgate.net)

Status of Karnataka's Fluoride concentration in Drinking Water

In Karnataka, the distribution of fluoride levels follows a similar pattern to that described for India as a whole. Fluoride concentrations in drinking water vary across different regions of the state, with darker areas on the map indicating higher fluoride levels and lighter areas representing lower concentrations. Understanding the geographic distribution of fluoride levels in Karnataka is crucial for assessing the potential health risks associated with fluoride exposure. Certain regions within the state may have geological characteristics that contribute to elevated fluoride content in groundwater, particularly areas with fluoride-rich geological formations. These regions, typically found in parts of northern and central Karnataka, may exhibit darker shades on the map, indicating higher fluoride concentrations. Conversely, regions with lighter shades on the map may have lower fluoride levels and may not face as significant health risks associated with fluoride intake. These areas could include parts of southern Karnataka or regions with geological formations that are less conducive to high fluoride content in groundwater.

Public health initiatives in Karnataka aimed at mitigating the risks associated with fluoride exposure may include measures such as water fluoridation, where appropriate, to ensure that fluoride levels in drinking water remain within safe limits. Additionally, monitoring of fluoride levels in drinking water sources is essential for identifying areas of concern and implementing targeted interventions to address fluorosis prevention. Public education campaigns on safe fluoride intake practices are also essential in Karnataka to raise awareness among the population about the potential health risks associated with excessive fluoride intake and the importance of accessing safe drinking water sources. By analyzing fluoride level distribution in Karnataka, policymakers and health authorities can better allocate resources and implement strategies to ensure access to safe drinking water for all populations across the state, thereby reducing the incidence of fluorosis and promoting public health.

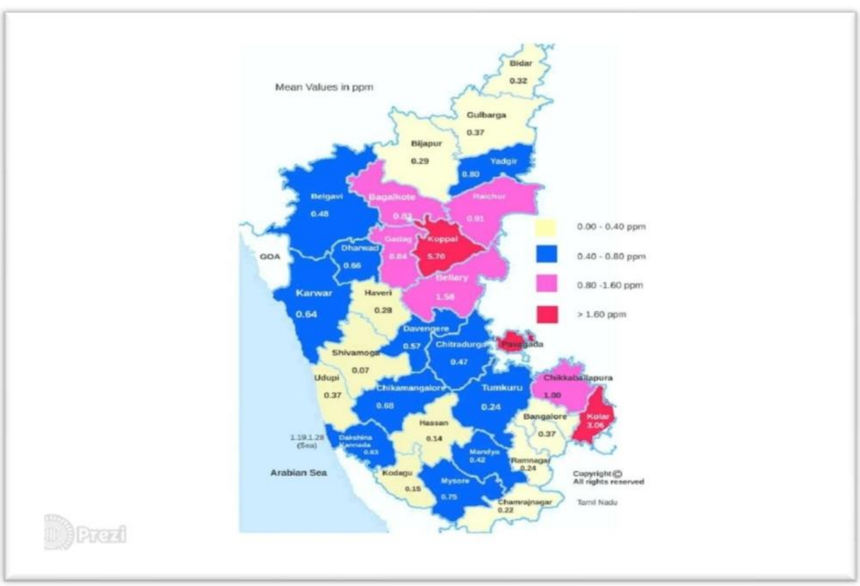


Fig: 1.2 Variation of fluoride concentration in Karnataka

Source: https://www.researchgate.net/profile/Raman-Bedi-3/publication/292990525/figure/fig1/AS:614130394337287@1523431504951/figure-fig1.png

.Proposed Idea

As mentioned above, in Mandya district, fluoride is high in some parts of the district. To remove this excess fluoride in drinking water in Mandya district, we are developing a low-cost water filter to remove fluoride using Biochar, using locally available low-cost materials available in market. By doing research and tests on the above-mentioned materials, we came to know that Biochar canbe used to remove the excess fluoride content.

By keeping all the above-mentioned points into consideration here is an attempt to develop a water filter to reduce fluoride in drinking water using low-cost materials like Rice husk, Watermelon rindand Coconut shell in the production of Biochar and mainly the attempt is made to cut down the price of water filter to come under Rs. 1000. By doing this project, we are not only providing low-cost water filters, it also helps to save lives from various water-borne diseases by providing clean drinking water.

OBJECTIVES

The objective divided as main objectives and specific objectives1.MAIN OBJECTIVES

- The main objective of the project is to develop filter at low cost which could serve the society byremoving Fluoride content.

2.SPECIFIC OBJECTIVES

- To select the types of feedstocks to produce biochar.
- To determine the adsorption capacity of the different biochar prepared.

- he biochar which has the maximum adsorbing capacity of fluoride content in the filter.

STUDY AREA

3.1 Study Area & Water Sample Collection

We have identified certain regions in the Mandya district (12.5218° N, 76.8951° E) where the drinking water contains undesired fluoride by examining the research on water quality evaluation. The drinking water in and around Krishnaraja Pete (K.R. Pete) taluk (12.6592° N, 76.4882° E), a few areas of Mandya city, and the areas in and around Maddur (12.5867° N, 77.0453° E) and Nagamangala taluk (12.8271° N, 76.7596° E) are prone to higher fluoride concentrations. These locations will provide a water sample, which will be brought to the lab to be tested for fluoride using a spectrophotometer and other preliminary methods.

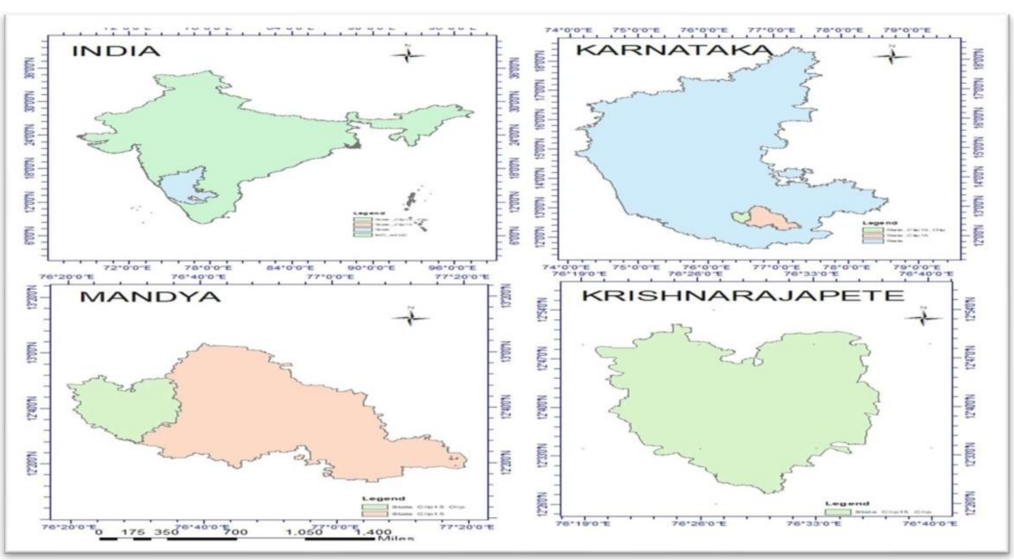


Fig 3.1: Study area showing Krishnaraja Pete

TALUKA	FLUORIDE (mg/l)
Mandya	0.7-0.9
Maddur	4.8-5.2
Malavalli	1.2-1.3
Krishnarajapet e	2.6-2.8
Pandavapura	0.6-0.8
Srirangapatna	0.6-0.8
Nagamangala	1.4-1.8

Table 3.1: Displays the different concentration levels of fluoride content in different taluk ofMandya district.

Previous year report reference: Chinmay, (2022), Development of low-cost water filters for theremoval of fluoride and hardness.

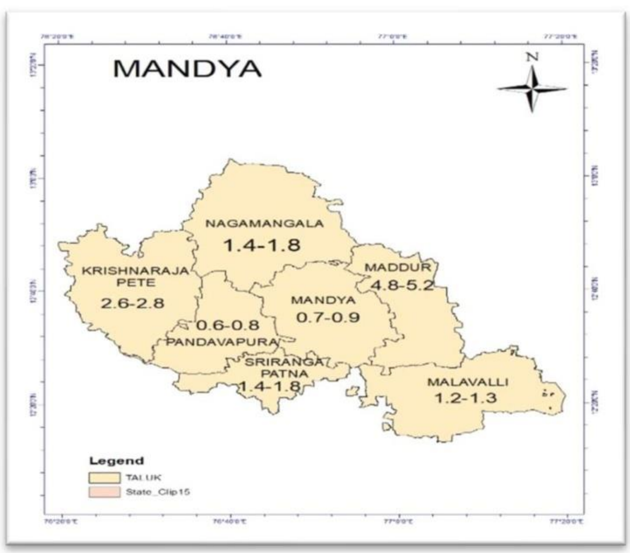


Fig 3.2: Study area showing fluoride levels in Mandya district.

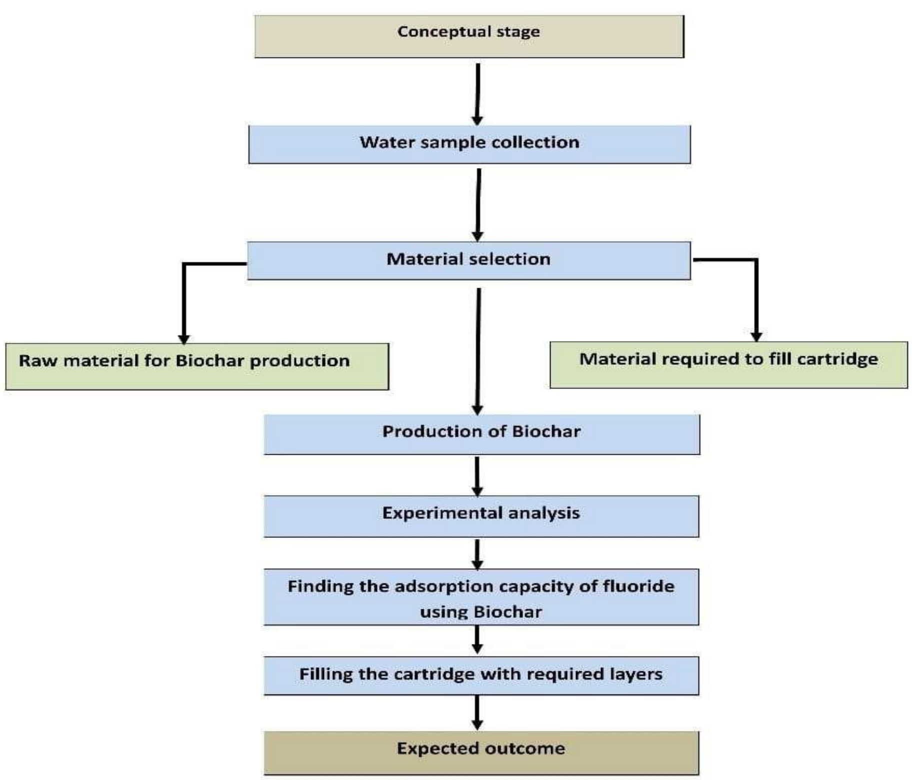
Methodology

General

This chapter briefly reveals the methodology followed in developing a low-cost water filter model. It gives an account of the materials used and their properties. It explains the tests and the procedure used to analyse water quality.

Proposed Methodology

The given methodology is followed in developing a low-cost water filter.



Conceptual Design:

The primary goal of the project is to remove fluoride from drinkable water as cheaply as possible. Avariety of locally accessible feedstocks were chosen in order to create biochar. Next, an engineering study is done to see if biochar can remove fluoride from drinking water

Materials Selection:

In Mandya District, the selection of rice husk, coconut shell, and watermelon rind as raw materials for biochar production offers a promising avenue for sustainable waste management and agricultural valorization. With rice husk being readily available from local rice milling industries, coconut shell abundant due to the region's tropical climate and watermelon rind sourced from seasonal agricultural activities, the initiative taps into the area's rich agricultural resources. This selection not only addresses waste disposal challenges but also presents economic opportunities by converting agricultural byproducts into value-added biochar. Additionally, the utilization of these locally sourced materials aligns with Mandya's environmental

objectives, promoting resource efficiency and reducing the environmental footprint associated with waste disposal. Through this strategic material selection, Mandya District advances its goals of fostering a circular economy and promoting sustainable agricultural practices.

Fig 4.1: Rice Husk Fig 4.2: Coconut Shell Fig 4.3: Watermelon Rind

Production of Biochar:

The selected raw materials were chopped into small bits after being cleaned,

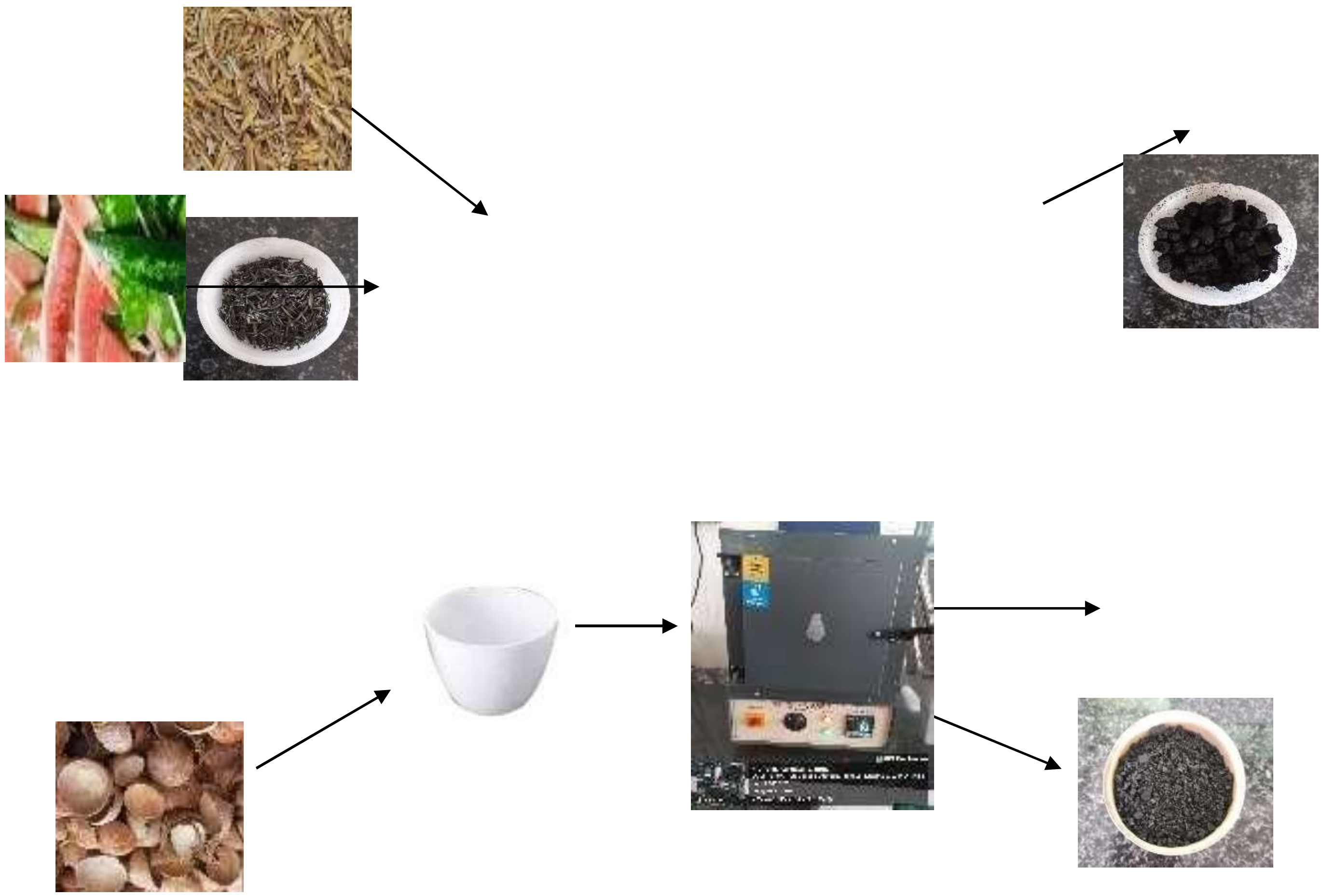


Fig 4.4: Flowchart showing production of Biochar

Materials Properties

The below table depicts the materials considered in the present study to remove the Fluoride concentrations in the water sample and its removal capacity.

MATERIALS	REMOVAL CAPACITY
Rice husk Biochar	Fluoride
Quartz sand	Hardness
Coconut shell Biochar	Fluoride

Table 4.1: Showing Material and its removal property

Quartz Sand

Quartz stone is crushed to create quartz sand. Quartz is a silicate mineral that is non-metallic, complex, resistant to wear, and chemically stable. With a Mohs hardness of seven, quartz sand is either milky white in colour or colourless and translucent. The technology for using quartz sand filtermaterial in multi-media filters is extremely advanced. Water treatment commonly uses quartz sand filters. When used as a filtration media, quartz sand can efficiently hold suspended solids, organic debris, colloidal particles, microbes, chlorine, odour, and some heavy metal ions if, under specific pressure, the water's increased turbidity flows through it. Moreover, it aids in softening drinking water. About 1 to 5 mm is the size of the quartz gravel sand that is used. The supplier of quartz sandis ET.

Fig 4.5: Quartz sand

Rice husk Biochar

Rice husk biochar, derived from the pyrolysis of rice husks, holds significant importance in water filtration due to its unique properties and capabilities. This carbon-rich material, produced through a process of heating rice husks in a low-oxygen environment, exhibits a porous structure with a high surface area, making it an effective filtration medium. When used in water treatment processes, rice husk biochar acts as a natural adsorbent, capable of capturing and removing contaminants such as heavy metals, organic pollutants, and pathogens from water sources. Its porous nature allows for the physical trapping and chemical binding of impurities, resulting in improved water quality. By utilizing rice husk biochar for water filtration, communities can access asustainable and environmentally friendly solution for purifying water, mitigating the risk of waterborne diseases, and promoting public health. Moreover, this approach not only addresses water quality concerns but also contributes to the sustainable management of agricultural waste, as rice husks are abundantly available byproducts of rice production. Thus, the utilization of rice husk biochar in water filtration exemplifies its dual role in environmental stewardship and public health advancement, offering a versatile and impactful solution to water treatment challenges.

Fig 4.6: Rice husk Biochar

Coconut shell Biochar

Coconut shell biochar, derived from the pyrolysis of coconut shells, is a versatile and sustainable material with significant importance in water filtration applications. Produced through a process of heating coconut shells in a low-oxygen environment, coconut shell biochar exhibits a porous structure and high surface area, making it highly effective as a filtration medium. When used in watertreatment processes, coconut shell biochar acts as a natural adsorbent, capable of removing a wide range of contaminants from water sources. Because of its porous nature, contaminants like organic pollutants, heavy metals, and pathogens can be physically trapped and chemically bound, increasingthe quality of the water. Communities can have access to a sustainable and eco-friendly method of water filtering, which lowers the risk of waterborne illnesses and improves public health by using coconut shell biochar. Since coconut shells are a byproduct of the coconut processing industry, the creation of coconut shell biochar also helps with the sustainable management of coconut waste. Because coconut shell biochar is made from waste materials and provides a sustainable solution to

water treatment problems, it not only tackles issues with water quality but also promotes environmental sustainability.

water treatment problems, it not only tackles issues with water quality but also promotes environmental sustainability.

Filling the cartridge with required layers

For Fluoride

An 8-inch cartridge is utilized for experimental investigation in order to prepare the filter cartridge for the removal of fluoride. 25% (5g) of rice husk biochar is added to the first layer, and the separator is added after each material. 25% (30g) of coconut shell biochar is utilized in the second layer, and 50%–100g of quartz sand makes up the third layer.

SL NO.	MATERIALS	QUANTITY %
1	Coconut shell Biochar	25
2	Rice husk Biochar	25
3	Quartz sand	50

Table 4.2: Quantity of Adsorbents used in the preparation of filter unit for fluoride removing.

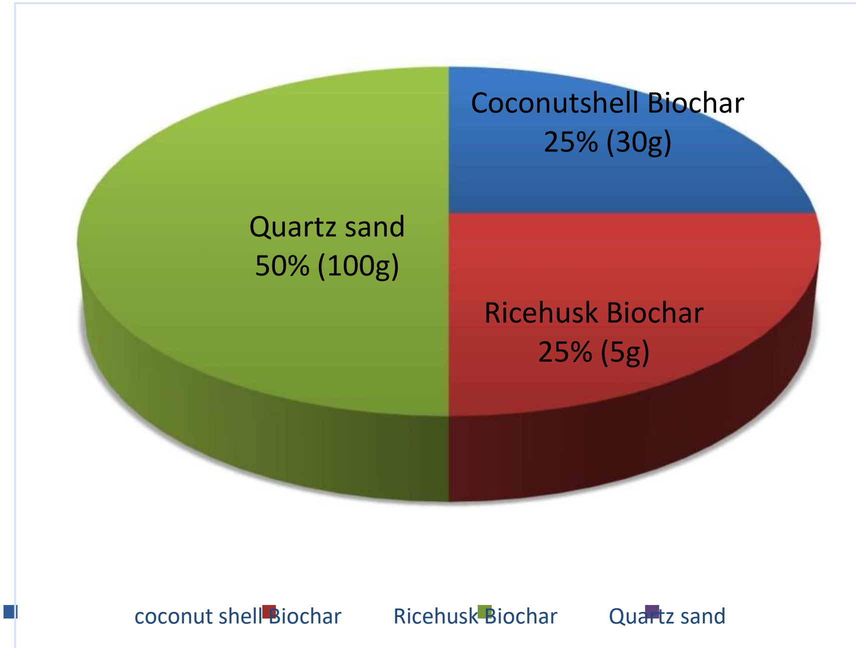


Fig 4.8: Pie chart showing the quantity of materials used in filter cartridge preparation for fluorideremoval.

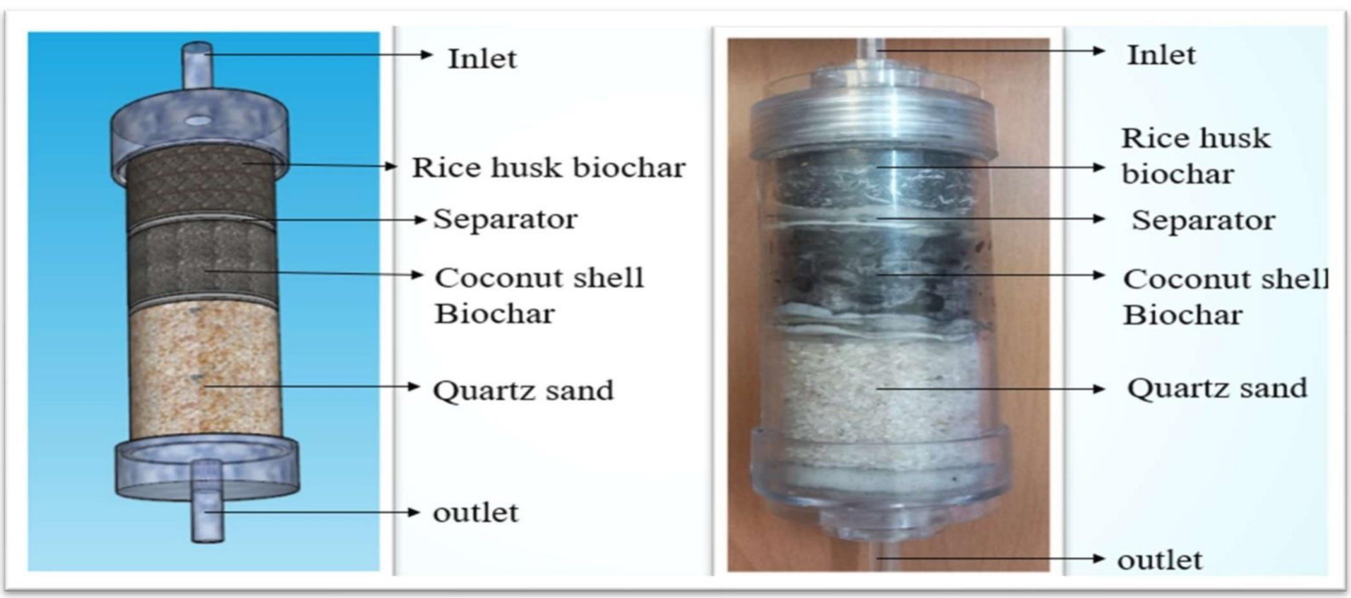


Fig 4.9: Arrangement of materials in filter cartridge.

Experimental Analysis:

Testing procedure for Parameters of water quality

- Standard procedures are followed to determine the water sample's water quality parameters.
- The pH, TDS, optimal dosage, and fluoride content of the water sample are examined.
- Each sample container was brought to room temperature in the laboratory prior to the commencement of the water quality examination.
- Next, based on the type of parameter, the necessary volume of water was extracted for the analysis. The steps and process for determining the parameters are listed below.

Determination of pH

Apparatus: pH meter along with electrodes.

Method: Electrometric method.

Reagent: Buffer solution.

Fig 4.10: p^H meter

Procedure:

1. Switch on the instrument and wait for 5 to 10 minutes for warming. Rinse the electrode thoroughly with distilled water and carefully wipe with tissue

paper.

2. Calibrate the pH meter by using Buffer solution. Press the Cal button, put pH7 buffer solution, and immerse the electrode for 1 or 2 min. After pH 7 wash the electrode with distilled water and wipe with tissue paper. Put pH 4 or pH 9.2 buffer solution and press Enter button.

3. After calibration, rinse the electrode thoroughly with distilled water and carefully wipe it with tissue paper.

4. Dip the electrodes into the sample, swirl the solution and wait up to one minute for steady reading. A pH meter reading within ±0.1 pH unit will be adequate for such work.

5. The reading is taken after the indicated value remains constant for about a minute.

Determination of Fluoride Concentration

Method: alizarin visual method (SPADNS)

Apparatus: Spectrophotometer, pipette, measuring cylinder.

Reagents: SPADNS reagent (Zirconium Alizarin)

Fig 4.11 Spectrometer with SPADNS reagent (Zirconium Alizarin)

Procedure:

SPADNS method:

1. Switch on the instrument and weight for 5 to 10 min. for warming
2. Press Enter button for conformation of the empty chamber
3. Select fluoride by using the up and down arrow key or Press 170 button and Enter button
4. Take 10 ml of distilled water in a cuvette, keep it in a sample chamber, and press the ZERO button.
5. After zero setting, take 10 ml of water sample in another

cuvette and add 2 ml ofSPADNS reagent and shake well.

6. Keep the cuvette in a sample chamber and Press the TEST button
7. Note down the Fluoride concentration in mg/l.

results and discussions

Factors Affecting the Adsorption Capacity Biochar

1. Feedstock Type: Influences biochar's composition and surface properties
2. Surface Area and Porosity: Higher surface area and pore volume enhance adsorption capacity.
3. pH: Affects surface charge and speciation of adsorbates.
4. Activation and Modification: Biochar’s or those modified with specific functional groups canexhibit enhanced adsorption capacities for fluoride.

Adsorption capacity of Biochar:

Finding out if the biochar can absorb fluoride was the main goal of the test. Prior to gathering the feedstocks from local markets, we first chose those that are easily accessible in Mandya. The biochar was made by employing the pyrolysis process. The experiment involved taking six beakers and filling each one with one litre of water that was known to contain fluoride. Then one gram of each of the following three biochar's was added: rice husk, watermelon rind, and coconut shell biochar went into the first three beakers; the remaining three beakers received 0.5 grams of each of these biochar's. Every beaker had a 150-rpm rotation and a one-day dwell period. The water in each beaker was filtered using Whatman filter paper, and each sample was subjected to the fluoride test. In the beaker, the adsorption efficiency was 92%; in the other beakers, it was 42%, 49%, 75%, 1.63%, and 35.8%. This revealed to us that the adsorption capacity of watermelon rind is low and that of coconutshell biochar is great.

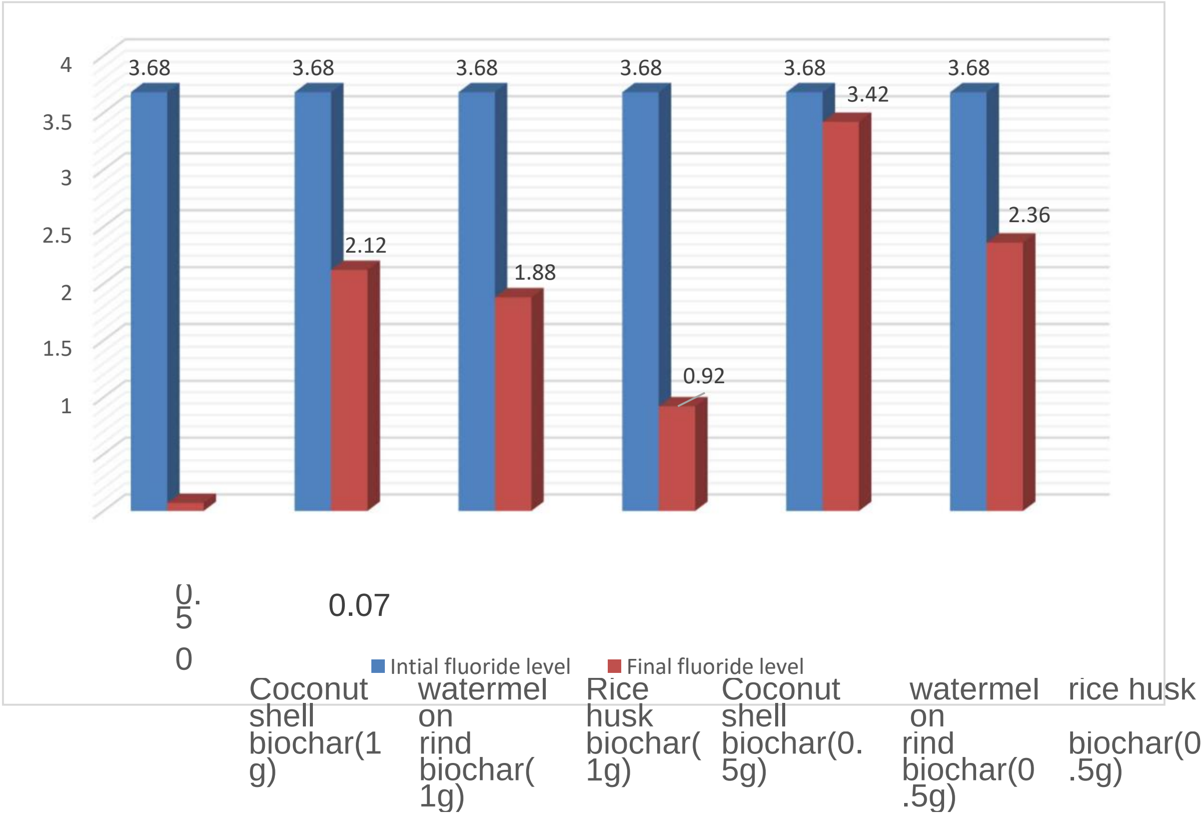


Fig 5.1: Variation showing adsorption capacity of Biochar

ANALYSIS FOR REMOVAL OF FLUORIDE

The goal of the experimental analysis was to determine the amount of each adsorbent needed to remove fluoride, as well as the impact of pH, contact time, and adsorbent dosage on the effectiveness of fluoride removal. Adsorption is also the general mechanism via which fluoride is removed. Adsorption is the method used in the production of rice husk and coconut shell biochar. We also learned from this research that the watermelon rind biochar had the ability to alter the color of the water, while the other two biochars had no effect. As a result, we removed the watermelon rind fromthe cartridge and used a jar test to determine each biochar's adsorption capability.

ANALYSIS OF FLUORIDE IN KRISHNARAJA PETE BORE WATER

Test No.	Date	Initial Fluoride level (mg/L)	Final Fluoride level (mg/L)	Efficiency(%)
1	23/04/2024	3.68	1.15	68.75
2	30/04/2024	3.68	0.88	76.08
3	07/05/2024	3.68	0.95	74
4	14/05/2024	3.68	1.05	

Table 5.1: Fluoride level assessment in Krishnaraja Pete bore water.

By conducting fluoride tests on the samples collected from the Mandya district, the sample from Krishnaraja Pete bore water had 3.68mg/l of fluoride concentration, which is more than the permissible limit prescribed by the BIS. Hence, this sample from Krishnaraja pete is selected for fluoride removal filter unit analysis. The adsorbents used for defluoridation are 25% (5g) of Rice husk biochar,25%(30g) coconut shell biochar and 50%(100g) of quartz sand has been used. The fluoride removing efficiency of the filter is found by conducting tests on the filter unit by passing the water in the filter unit; due to the passing of fluoride water through the adsorbents, by adsorption process, the materials in the filter cartridge start to defluoride the water. The highest efficiency achieved by this filter unit is 76.08%. Therefore, this filter can be used in the places where the fluoride concentration level is between 2-3.5mg/l. Figure 5.6 shows the variation in fluoride level in Krishnaraja Pete bore water before and after the treatment. Figure 5.7 shows the efficiency of the fluoride removing adsorbents with the passage of t

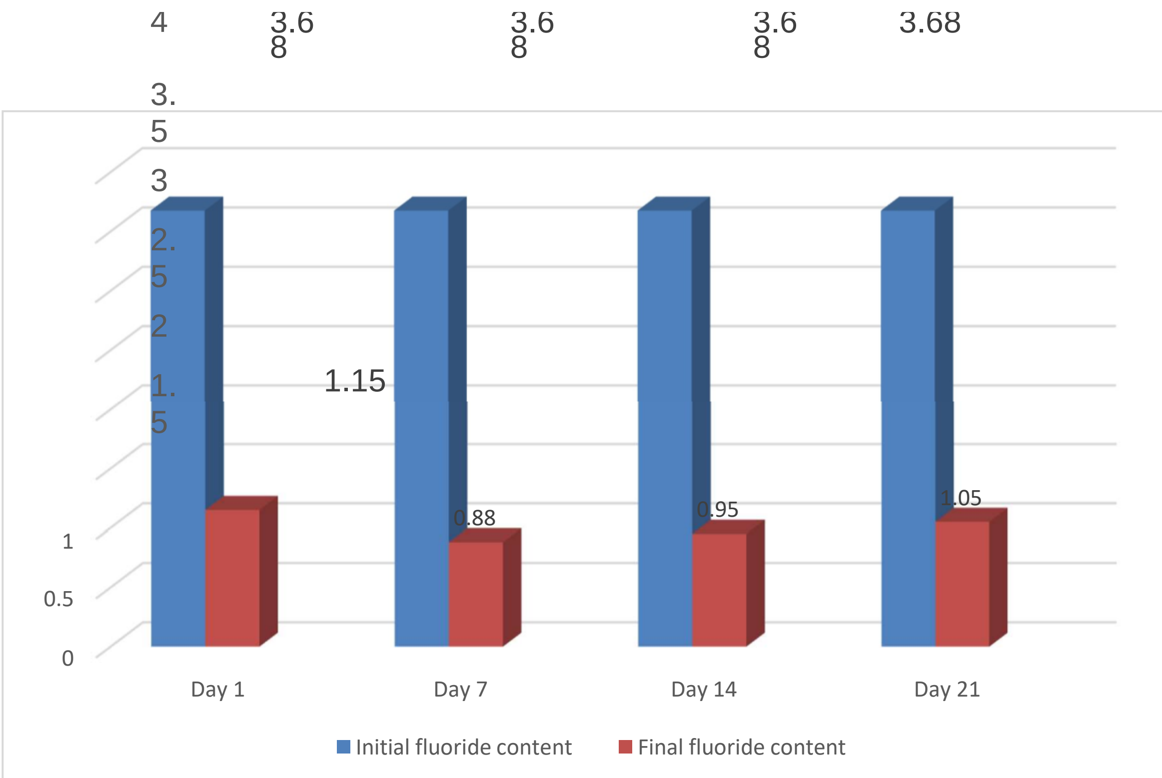


Fig 6.2: Variation of fluoride level in bore water after purifying.

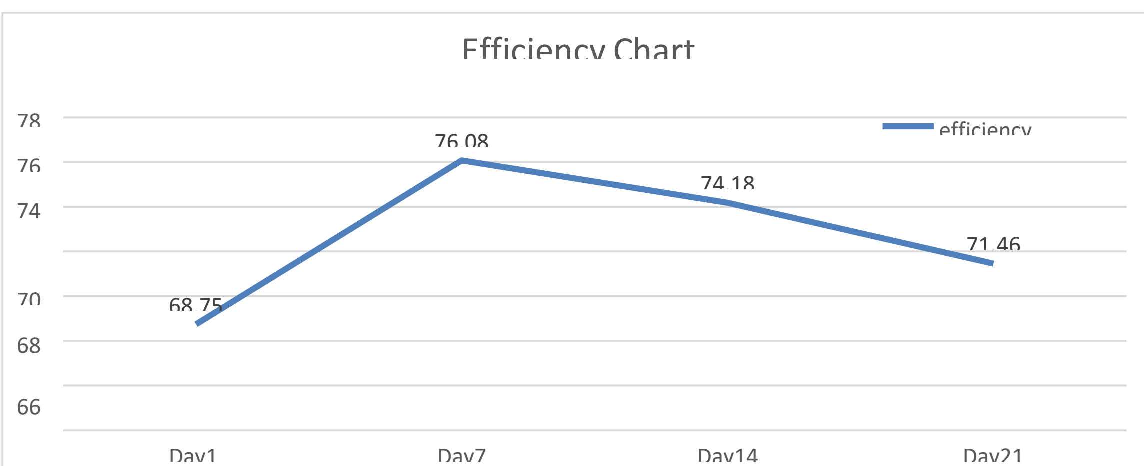


Fig 6.3: Chart showing the efficiency of the fluoride removing adsorbents with the passage of time

Fluoride Concentration

Trail No.: 01 Date: 23rd April 2024

Sample Details: Krishnaraja Pete

bore waterInitial Test:

Initial Fluoride Concentration (mg/l): 3.68

Materials Proportions in Filter Media:

Sl no.	Name	Quantity (grams)	Cost (Rs.)
1	Coconut shell Biochar	30	-
2	Rice husk Biochar	05	-
3	Quartz sand	100	30
Total cost of materials			30

Duration:
Instant flow
Flow Rate:

Final Test:

Final Fluoride Concentration (mg/l): 1.12

Efficiency of Filter Media:

$$Efficiency = \frac{Initial\ fluoride\ concentration - Final\ fluoride\ concentration}{Initial\ fluoride} \times 100$$

$$Efficiency = \frac{3.68 - 1.15}{3.68} \times 100$$

$Efficiency$ = 68.75%

Total Cost: 30+ 200 (approximate cartridge cot) = 230 ~ 250Rs.

INNOVATION IN THE PROJECT & FUTURE SCOPE

Project Innovation:

Access to clean drinking water is a fundamental human right, yet millions of people worldwide suffer from diseases caused by excess fluoride in their water. Fluorosis, resulting from prolonged ingestion of high fluoride levels, can lead to severe dental and skeletal damage. To address this pressing issue, a novel low-cost water filter has been developed, utilizing biochar produced from locally available materials such as rice husk, coconut shell, and quartz sand. This innovative approach not only offers an effective solution for fluoride removal but also champions sustainable waste management and environmental protection.

Scope of Future Work:

- Research into modifying biochar properties to increase fluoride adsorption capacity can furtherimprove filter efficiency.
- Implementing affordable biochar filters can significantly reduce the incidence of fluorosis andother fluoride-related health issues in affected communities.
- These filters can be especially beneficial in rural and low-income areas where access toadvanced water purification systems is limited.
- If these filters are developed in a larger scale, society can be benefitted.