DEVELOPMENT OF LOW COST WATER PURIFICATION TECHNIQUE

NIT ROURKELA

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF ALL REQUIREMENTS OF THE DEGREE OF

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

BY

LOPAMUDRA PRIYADARSINI

UNDER THE GUDANCE OF

Prof. Somesh Jena

Prof.Ramakar Jha

Department of Civil Engineering

National Institute of Technology

Rourkela

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CERTIFICATE

This is to certify that the project entitled "Development of low cost water purification technique" by Miss. Lopamudra Priyadarsini [Roll no 109CE0059] in partial fulfillment of the requirements for the award of Bachelor of Technology degree in Civil Engineering at National Institute of Technology (Deemed University) in an authentication work carried out by her under my supervision and guidance.

To the best of my knowledge the matter embodied in the project has not been submitted to any other university/institute for the award of any degree or diploma.

Date: 10 May 2013.

Prof. Somesh Jena

Prof. Ramakar Jha

Department of Civil Engineering

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Acknowledgement

My heart pulsates with the thrill for tendering gratitude to those persons who helped in completion for my project. The pleasant point of presenting a report is the opportunity to thank those who have contributed to build my knowledge. Unfortunately, the list of expressions of thank no matter how extensive is always incomplete and inadequate. Indeed this page of acknowledgement shall never be able to touch the horizon of generosity of those who tendered their help to me.

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Lopamudra priyadarsni

Roll no- 109CE0059

B-Tech 8th semester

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Abstract

About one-fifth of people on earth lack the access to safe drinking water, a condition that resulted in the death of 2.2 million people in 2004, as per the records of United Nations. Clean water use being a prime concern in many communities of developing countries. Contaminated water plays significant role in taking numerous lives in these localities, for which a number of efforts are being made for accessing safe purified drinking water. Fortunately, efficient and cheap water purification systems are being utilized and being tried to be accessed worldwide for easy access to clean water.

In the following project we had tried to develop a "Low Cost Water Purification Technique" using the basic ideas of Slow Sand Filter, some locally available filter material like charcoal, bone char, sand, manganese modified sand, clay, rice husk, banana residue ash, anthracite and try to improve the methodology using the UV Filter, RO Filter, and Activated Carbon Filter mechanism. Main focus was removal of iron from surface water by adsorption and oxidation followed by precipitation technique. Among all the adsorption media used, manganese modified sand proved to be a good adsorbent in removal of iron. For oxidation followed by precipitation, the ash produced from banana residue was used which proved to give the best result in removal of iron and also was having the cheapest material cost. A ceramic membrane with locally collected clay and rice husk was prepared which also proved to be effective for removal of turbidity, but may be due to rigorous use of the filter or any manufacturing defect, there were cracks developed on its surface and was discarded for any further use.

CHAPTER 1

INTRODUCTION

1.1 General

Purified water is essential for living a healthy life as such everyone should have access to it. Drinking water conditions have great impacts on people's everyday life, especially in the rural and remote areas where access to safe drinking water is very crucial. Surface water often is the only source, thus water contaminations are difficult to avoid due to rigorous and reckless use of surface water. Unsafe drinking water may result in fatal diseases. Statistics shows that these diseases resulted in ninety percent of all deaths of children under five years old in developing countries, due to low immunization of children to infections.

Despite of fulfillment of requirement of drinking water standards, the municipal water in used in developing countries is being improved and cost efficient water filtration techniques are being developed commonly used to improve taste or to eliminate any undesired matters. Various types of filters have been designed to be more suitable for the rural areas of the countries, but the cost as well as the filter effectiveness is still not satisfactory and further improvement is still required.

Drinking water is being the biggest issue nowadays in India. Most of the people in the rural areas are not able enough to use water filters or buy mineral water bottles. To overcome this problem many efforts have been done due to which cleaning water may become an affordable commodity. Every house hold should be able to develop its own drinking water purification system; this should be the aim of development of any low cost water purification technique.

In this context a number of contributions that has been made where the filter media varies from a layer of simple cotton cloth to composite nano materials. Some of the typically used water filtration methods in India have been discussed here.

In some of the rural areas of Karnataka, women use cotton cloth layers for water filtration. This method is very cheap, cost effective in removal of sediments or any suspended solids, but may be not completely suitable for drinking purpose. Some places people are using simple plastic bottles with open end, inside which a layer of bone char followed by a layer of sand and a layer of pebble on both sides of the bone char layer is being used through which water will be passed for filtration. This kind of filtration process is capable of removing sediment and microbes effectively from water.

Solar distillation and solar sterilization are the recent but convenient technologies developed as a low cost water filtration process. In this process water filled clean plastic bottles are left in sun for several hours so that the UV radiation and the heat generated will be able to kill the microbes present in water causing many water borne diseases. Now these methods are improvised by using thermal indicators inside the bottle letting the users know when it will be safe to drink the water. But despite of being cheap and effective, this method is a function of availability of solar light. So maybe not abundantly used in water purification process. In comparison with solar sterilization, the solar distillation technique is even capable of purifying muddy water or salty water through the process of evaporation and condensation.

Among widely used naturally occurring adsorption media, bamboo charcoal provided with base gravel layer also is very effective in purifying water with the advantages of being low coat, environment friendly and requires minimum maintenance. Activated carbon, silver beds, charcoal, sand is being widely used in portable filters for disinfection and filtration of water.

Bone char is proved to be very efficient in removing heavy metal ion s from water, the excess amount of which can cause many fatal renal and cardiac diseases and high blood pressure.

Ceramic filters provided with saw dust or rice husk in the shape of pots are very much efficient in microfiltration which removes suspended solids and microbes to great extents. The main disadvantage is for small house hold purpose where pressure filtration is not an option; it has to be used for gravity filtration and thus the rate of filtration will be very much less and the filter requires continuous maintenance.

Recently IIT M has developed an effective low cost water filtration model specifically meant for rural areas which uses a cheap plastic mesh which is capable of removing 98 percent of impurities from water including pathogens. The cost of the filter is somewhat Rs 700 to 800 and very easy for reuse. Another recent development of IIT M is development of composite nano material used as a filter media which capable of removing toxic metal ions as well as killing the pathogens. The filter is worth rupees Rs 500 excluding the cartridge. Another attractive feature of this filter media is that the cartridge can be reused by simply boiling in water or rubbing with lemon juice which is easily available in common households.

India’s largest company Tata Group has developed a very cheap water filter known as “Swach”, cost of which is less than Rs1000. It uses nano-technology for filtration and silver particles for eradicating bacterial contamination.

Ultimately the aim of development of any low cost water filtration model should be to operate with minimum energy, minimum maintenance, cost effective, environment friendly, implementable with ease and can be developed from local artisans. This will subsequently inspire the people to put hygiene in to habit and of course will help in the social and economic growth of the country.

1.2 Objectives

The scope of this project is to study the existing water filtration methods, and use the knowledge to design a **Low cost water filtration technique**. This water filtration system will focus on cutting down the cost while maintaining filter effectiveness. By providing affordable water filters for the rural and remote areas, will greatly improve people's quality of living, and reduce the risk of any waterborne diseases therefore saving lives.

The basic objectives of the project are as follows.

- Removal of iron from water by using different adsorption media which are locally available at a low cost
- Development of a ceramic filter with clay and rice husk and studying the efficiency of removal of turbidity
- Designing a simple household setup for water filtration focusing on removal of iron and turbidity
- Cost estimation of all the adsorption media used as well as the ceramic filter
- Analysis of filtration effectiveness in removal of iron for different filter media

Chapter 2

Literature Review

- Hasan in 1990 studied the **c**ontact aeration for iron removal method. The iron removal process utilized the catalytic effect of ferric iron. Again in this experiment it was theoretically demonstrated that by keeping high concentration of ferric iron, the volume of the aeration tank can be significantly reduced and it was according to the oxygenation rate equation. Ferric iron is very much effective in decreasing the reactor volumes at lower pH values. It is proposed to recycle the ferric sludge to maintain the high ferric iron concentrations in the reactor.

- William, et al. in 1992 studied the impact of dissolved organic carbon on the removal of iron during water treatment. He used the iron removal process by oxidation and coagulation method. Humic and fulvic acids, tannic acid and oxalic acid were estimated in the organic content. Potassium permanganate, chlorine dioxide and free chlorine were used as oxidizing agent.

- Catherine in 1988 studied the control of biological iron removal from drinking water using oxidation-reduction potential. In 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 in the infiltrate by using a biological filter.

- Tomotada studied the Current bioremediation practice and perspective in 2001. In the method he used in-situ fluorescence hybridization (FISH), in situ PCR, and quantitative PCR for removal of contamination by bioremediation .In this method the detection and reorganization of bacteria and pathogens is very vivid and these are being directly related to the rate of degradation of contaminants.

- Wang, et al. in 2003 studied the removal of heavy metal ions from aqueous solutions using various adsorbents with minimal cost. He used various low cost adsorbents like Fe2O3, Fe3O4, 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.

- Choo, et al. studied in 2005 the removal of iron and manganese in ultra filtration and also the process of membrane fouling. He also examined to remove the residual chlorine due to pre-chlorination which is opted as a convenient option for safe drinking water. The membrane fouling was caused due to the oxidation of iron and manganese which was also visualized thoroughly at microscopic level and the steps for eradicating the degradation of membrane were proposed.

- Takerlekkopoulou, et al. studied in 2006 the physio-chemical and biological iron removal from potable water. He used the technique of trickling filter and constructed a model for it including the pilot-testing. The main mechanism was physio-chemical and biological oxidation of iron. The detailed chemical reaction and extent of each oxidation was studied. Experimentation was done with specified temperature, optimum feed iron concentration and volumetric flow rate. First order kinetics and Monod-type kinetics was observed in physio-chemical and biological oxidations respectively.

- Gupta studied in 2006 the non-conventional low-cost adsorbents for dye removal. He studied an extensive number of adsorbent for filtration and in the review he showed the critical analysis of these materials, characteristics, advantages, limitations and mechanisms of adsorption. He used activated carbon of agricultural solid waste, industrial by product, clay and materials containing silica.

- Bordoloi, et al. in 2007 studied the removal of iron from water using the ash produced from banana residue [14, 15, and 16].Ashes from different materials i.e. dry banana leaf, pseudo stem, rind, bamboo, rice husk were produced by controlled combustion. The mechanism of removal includes oxidation of iron at high pH or alkaline medium produced by potassium present in banana due to subsequent formation of potassium hydroxide. The study included analysis of chemical composition of banana ash and its efficiency in removal of iron from prefabricated water. Further it has been used in a low cost household water purification model in which after treated with ash, the water is being filtered with a cotton cloth and being used for drinking.

- Chaturvedi in 2012 studied the removal of iron for safe drinking water. He used the methods of iron removal from drinking water such as electro coagulation; oxidation filtration, ion exchange, lime softening, adsorption by activated carbon, BIRM media, Anthracite [1], green sand, pebble and sand mixture, ultra filtration etc have been discussed.
- Ganvir, et al. in 2011 studied the removal of fluoride from groundwater by aluminum hydroxide coated Rice husk ash [12, 13]. Activated aluminum hydroxide has been used for activating the RHA surface which forms a complex with fluoride ion in water and accelerates the process of removal.RHA was obtained by controlled burning of dry and crushed rice husk and treating with hydrochloric acid before activation.
- Simonis in 2012 studied the manufacturing a low-cost ceramic water filter [19] and filter system for the elimination of common pathogenic bacteria and suspended solids**.** A micro-porous ceramic water filter in which clay was mixed with rice husk in a ration 2:1 by weight and a cylindrical shaped filter was manufactured by tradition oven drying and then burning in kiln at specified sintering temperature. After being coated with silver nitrate solution for preventing the growth of microbes, the filter was tested for removal of suspended solids and pathogens.

CHAPTER 3

Filtration Model Development

And

Materials Used

3.1 Filtration Model Development

Here we have manufactured a simple cylindrical filtration tube as shown in figure 3.1(a) with the following dimension

Length = 30cm

Internal diameter = 8cm

Outer diameter = 10 cm

- Base is covered with a porous plate of 5mm diameter pores as per fig 3.1(c).
- From the base, a conical portion is extended to collect water with a tap as shown in fig 3.1(d) to regulate filtered water.
- Top of the cylinder was covered with a perpex sheet of 1 inch thickness as shown in figure 3.1(b)
- A hole of 2 cm diameter was made to connect with the inlet pipe.

In the proposed design of the model, the prefabricated water of known iron concentration was passed through the inlet pipe above. Inside the cylinder, different adsorption media of specified thickness were placed with proper gravel support. Then after filtration, the filtered water was collected through the conical part in a beaker and the final iron concentration was measured in the Atomic Absorption Spectrometer (AAS). The rate of filtration was noted and for each adsorption media, three samples were tested and average iron concentration was considered for analyzing filter effectiveness.

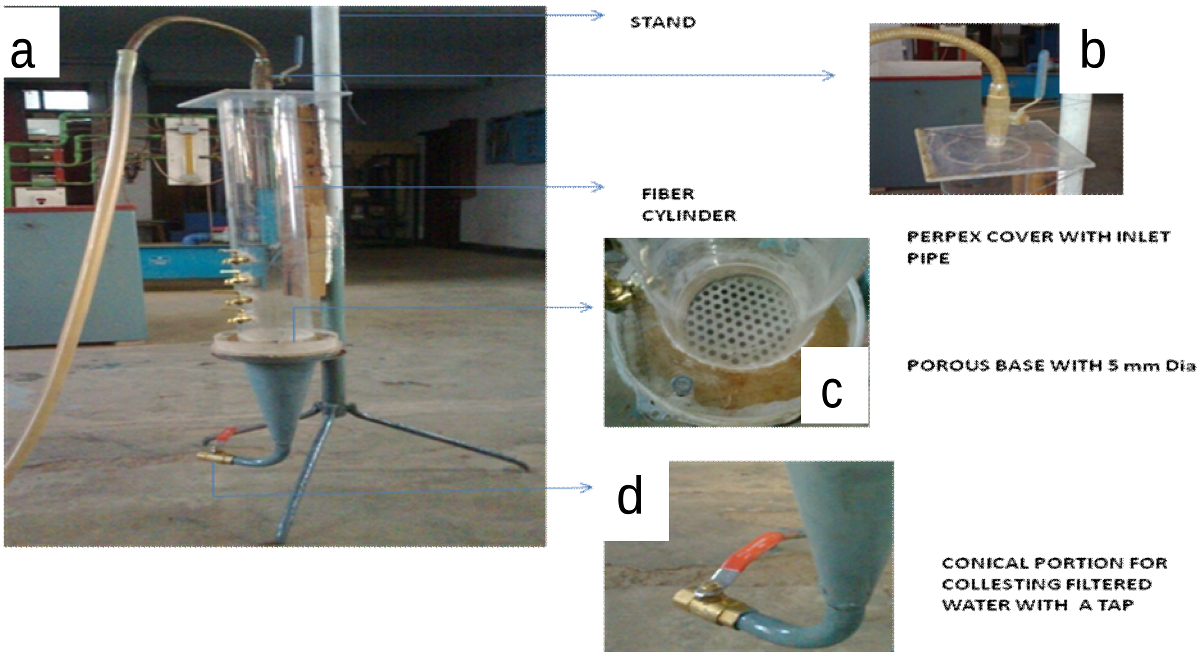


Fig. 3.1(a) Filtration Model, (b) Inlet pipe fitted with the perpex cover, (c) Porous base, (d) Conical portion for water collection

3.2 Materials used and Preparation of Adsorption Media

As per the two methods explained in 4.1 and 4.2, in the first method for removal of iron by adsorption technique, different adsorption media were used for iron removal are listed below which are locally collected at a very cheap cost. In the second methodology, ash obtained from banana residue was used for removal of iron by oxidation followed by precipitation as per 4.2.

3.21 Plane sand

Fine sand and gravel are naturally occurring glacial deposits high in silica content and low in soluble calcium, magnesium and iron compounds are very useful in sedimentation removal. But here the media is used for iron removal from drinking water [4]. Here for the experimentation plane sand passing through 425 micron and 600 Micron IS sieve were used.

3.22 Activated Carbon

Activated carbon [5, 6, and 7] of a used aqua guard carbon filter crushed to the size of 2mm and down was used for removal of iron from water.

Fig. 3.2 Activated Carbon of Aqua Guard crushed into size of 2mm and down

3.23 Wood Charcoal

Bituminous coal [3] has been used before as an adsorbent and proved to be very effective in removal of iron. Due to non-availability of bituminous coal, we used wood coal as an adsorbent media for experimentation. Locally collected wood charcoal crushed to size 10mm and down was used for removal of iron from water.

Fig 3.3 Crushed Wood charcoal of size 10mm and down

3.24 Wood charcoal and Rice husk mixture

Mixture of wood charcoal and raw rice husk in the ratio 3:2 by weight was taken for removal of iron from water as a trial without any prior evidence of being used as an adsorbent.

3.25 Manganese modified Sand

Sand passing through IS 850 micron sieve was collected as specified in 2.25 and cleaned with distilled water, dried in oven at 373K for 12 hours, soaked with 0.01N $KMnO_4$ for 24 hours and then washed thoroughly by distilled water and dried at 373k for 12 hours and cooled to room temperature. This was used as adsorbent media [10, 11].

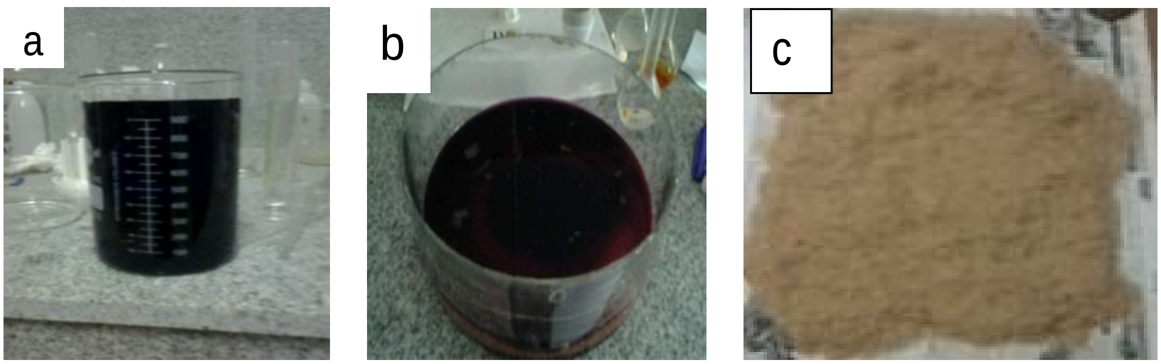


Fig 3.4(a) 0.01N $KMnO_4$, (b) sand soaked in 0.01N $KMnO_4$, (c) oven dry manganese modified sand

3.26 Anthracite

Crushed anthracite is an excellent medium density filtration media. Due to high carbon content, low specific gravity, cost effectiveness, this media has been used for simple filtration. It can compare with equivalent sand filter for better filtration efficiency and longer filter run [1]. But here well graded anthracite grains i.e., of size 625 micron and down have been used as an adsorption media for removal of iron.

Fig 3.5 Crushed anthracite of size 625 micron and down

3.27 Aluminum hydroxide coated Rise husk Ash

RHA (rice husk ash) was prepared by controlled burning process in muffle furnace at a temperature of 500 degree Celsius for 4 hours. The RHA was first soaked with 0.01 N HCl. Dry RHA of 100 gm, 0.6 M of aluminum salt (Aluminum Sulphate salt) solution and 3M sodium hydroxide was added and stirred for one hour and then the filtered RHA was kept in oven for 3 hours at 373 K [12, 13]. This was used as an adsorbent along with sand as a base material.

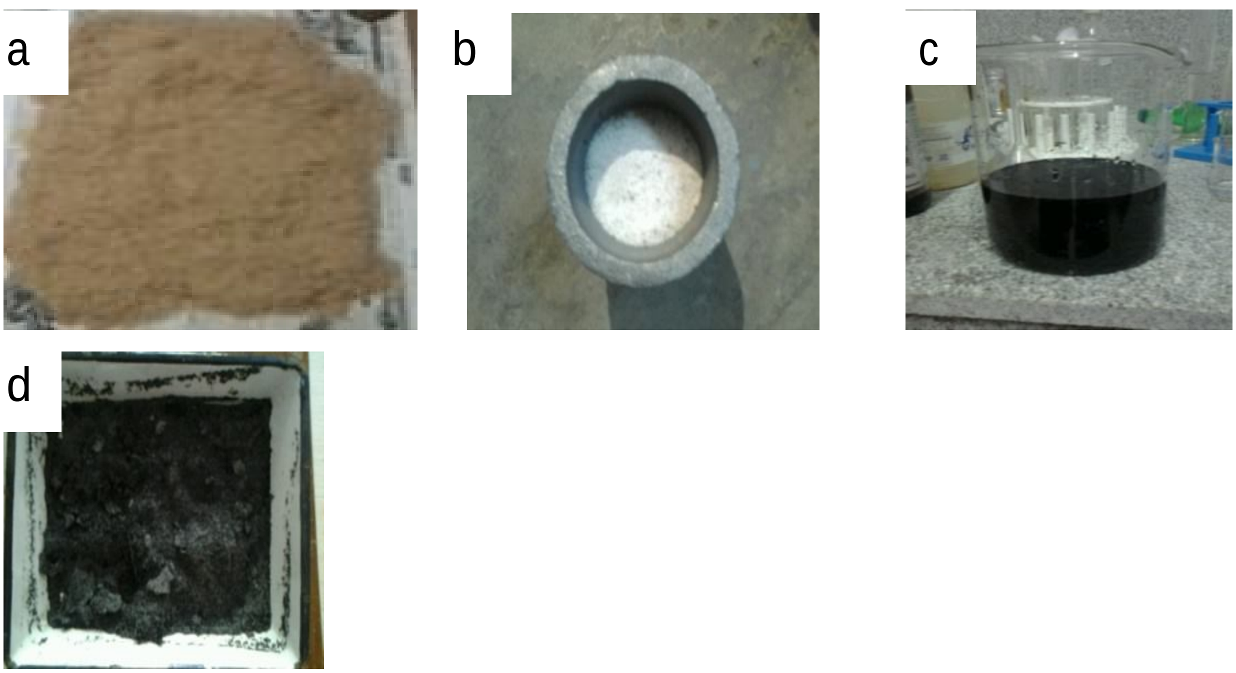


Fig 3.6 (a) Rice husk ash prepared after controlled heating at 500 degrees, (b) RHA soaked with 0.01N HCl, (c) Al(OH)3 coated RHA

3.28 Ash of banana leaf, Rind and stem

For this method dried plant material of banana tree i.e. leaves, rind, pseudo stem were collected and ash was prepared by heating at 500 degrees for 4 hours in oven [18].

Fig 3.7 Sun-dried banana leaf, pseudo stem and rind

For this method dried plant material of banana tree i.e. leaves, rind, pseudo stem were collected and ash was prepared by heating at 500 degrees for 4 hours in oven [18].

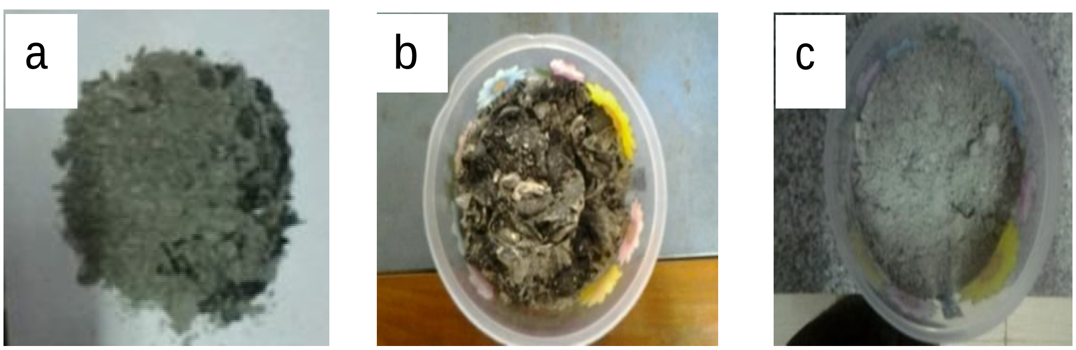


Fig 3.8(a) Ash obtained from dry banana leaf, (b) ash from dry banana rind, (c) ash from dry banana stem

3.29 Preparation of ceramic filter

Locally collected clay of size 75 micron and down was used for fabrication of a ceramic filter with rise husk. A mixture of clay and rice husk of size 425 micron and down with ratio 2:1 was made with admixtures boric acid, sodium meta silicate and sodium carbonate. The amount of materials taken was given below in the table where the cost of ceramic filter has been stimated.. After hand mixing the components for about 15 min, water was added in the amount of 1.25 lit/kg of rice husk. Then mixing was done properly for about 30 min. The mixture was then transferred to a cylindrical mould and dried at room temperature for about 48 hours. Then the mix took the shape of the mould and then dehydrated at 100 degree Celsius in oven for about 6 hours. Then the mould was kept in the muffle furnace for about 8 hours at a sintering temperature of 866 degree Celsius for complete bonding of the clay particles [19].

Fig 3.9(a) mixture of clay rice husk and admixtures, (b) cylindrical Mould, (c) filter after oven drying, (d) Ceramic filter after sintering at 866 degree Celsius

Chapter 4

Methodology

For removal of iron broadly two phenomena had been used in the experiments i.e. adsorption, oxidation followed by precipitation and for removal of turbidity microfiltration by ceramic filter has been adopted.

4.1 Adsorption

Basically the adsorptive filtration is operated under anoxic conditions for removal of iron where oxidation of ferrous iron is suppressed i.e. in case of filtration of ground water [1]. Here we have taken aerobic conditions for filtration in the adsorption media. Among some well known adsorption media like anthracite, olivine, magnetite, zeolite, sand, pumice, bituminous coal [2], carbonaceous shale [3] etc. The following adsorption media had been experimented here for removal of iron from drinking water.

Sand

Fine sand and gravel are naturally occurring glacial deposits high in silica content and low in soluble calcium, magnesium and iron compounds are very useful in sedimentation removal. But here the media is used for iron (Fe) removal from drinking water [4].

As per mentioned in 3.21, specified sand was taken and cleaned with distilled water and dried in oven for 6 hours at 373 k. After being cooled to room temperature, the sand was used in the filtration model previously developed with a gravel base of specified size to support the sand bed. Known concentration of 1000ml of iron solution was passed through the sand and the filtrate was collected in a beaker. The rate of filtration was calculated and final iron concentration was measured with AAS (Atomic Absorption Spectrometer).

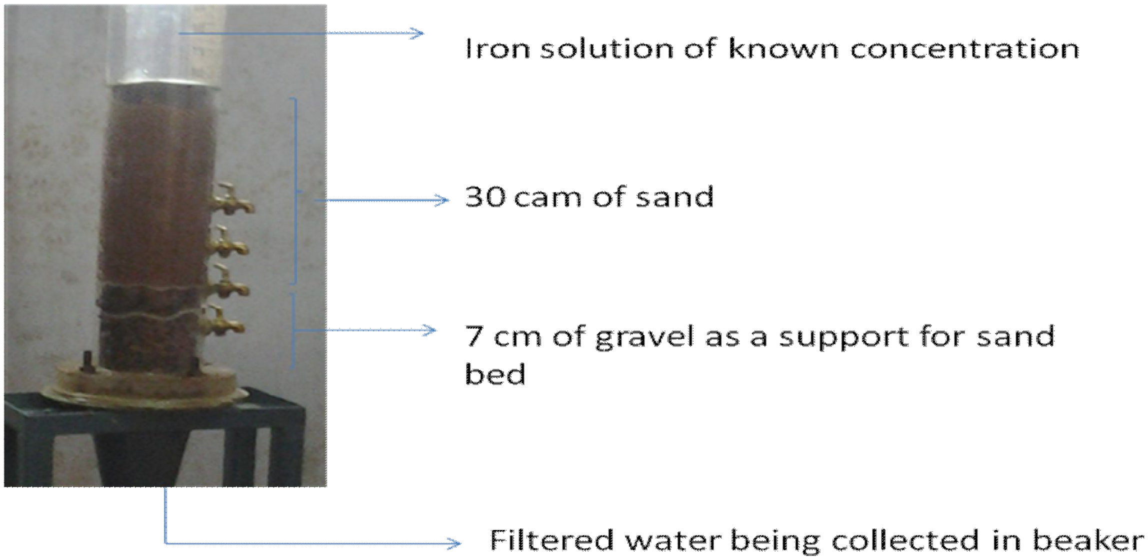


Fig 4.1 Filtration using plane sand as filter media

Activated carbon

The micro contaminates present in water cannot be effectively removed by traditional method where as the activated carbon proved to be very useful for removal of organic as well as inorganic contaminants [5,6,7].

As specified in 3.22, crushed activated carbon was obtained and used above sand bed of specified thickness in the filtration model for removal of water. For experimentation 1000 ml of iron solution of known concentration was taken and the filtered water was collected after filtration and the rate of filtration was noted.

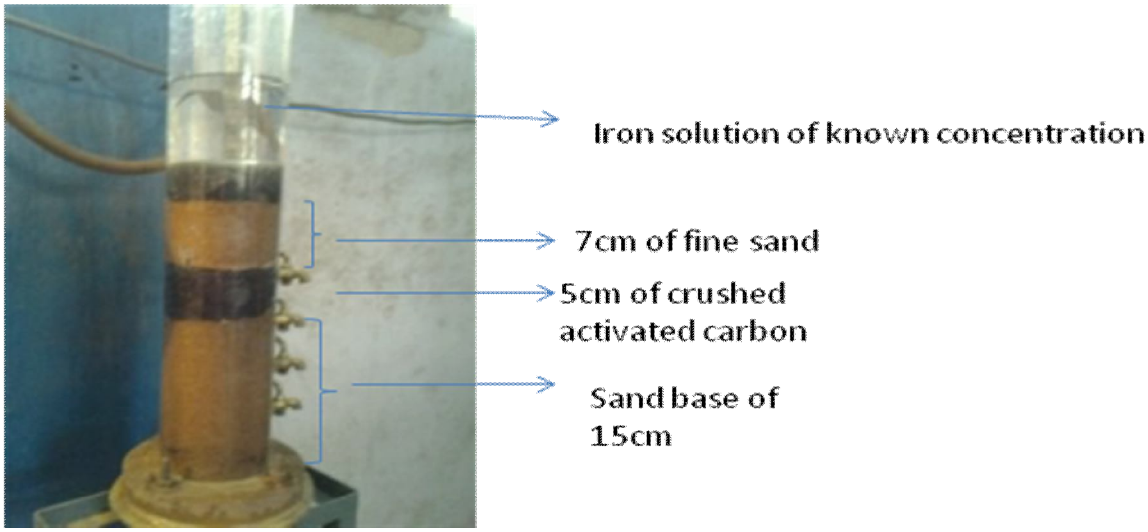


Fig 4.2 Filtration using Activated carbon as adsorption media

Wood Charcoal

Due to non-availability of bituminous coal [3] wood charcoal has been adopted as specified in 3.23 for using as an adsorption media. Wood charcoal of specified thickness was used as an adsorption media in the filtration media. For experimentation 1000 ml of iron solution of known concentration was taken and the filtered water was collected after filtration and the rate of filtration was noted.

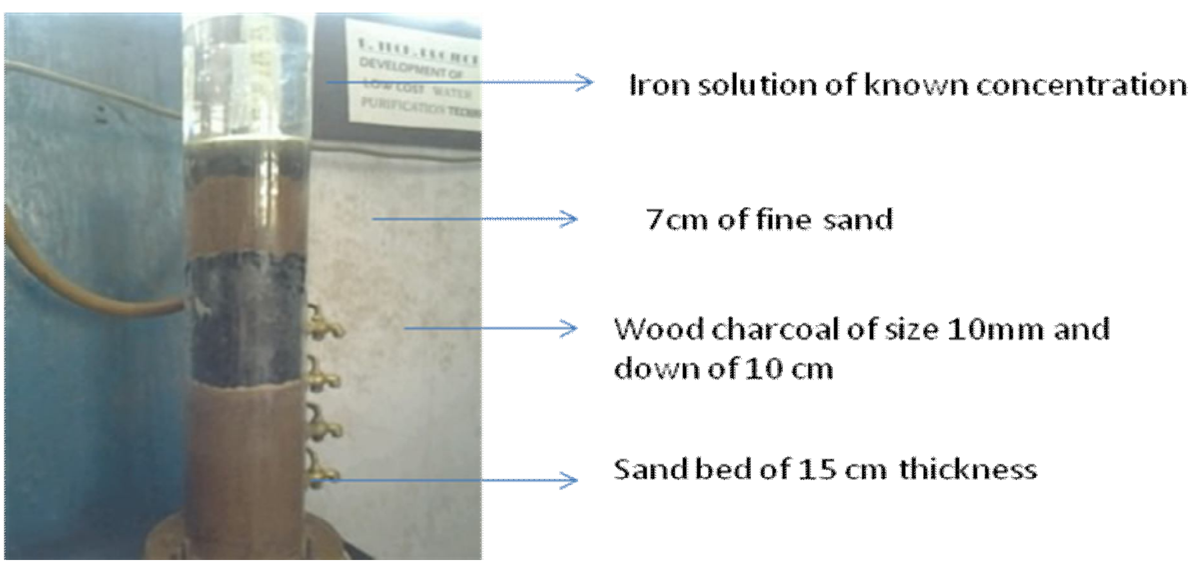


Fig 4.3 Filtration using wood charcoal as adsorption media

Wood charcoal and Rice husk mixture

Raw rice husk and charcoal was taken in a ratio 2:3 by weight and used as a filter media with sand as a base material of specified in 3.24 in the filtration model. For experimentation 1000 ml of iron solution of known concentration was taken and the filtered water was collected after filtration and the rate of filtration was noted.

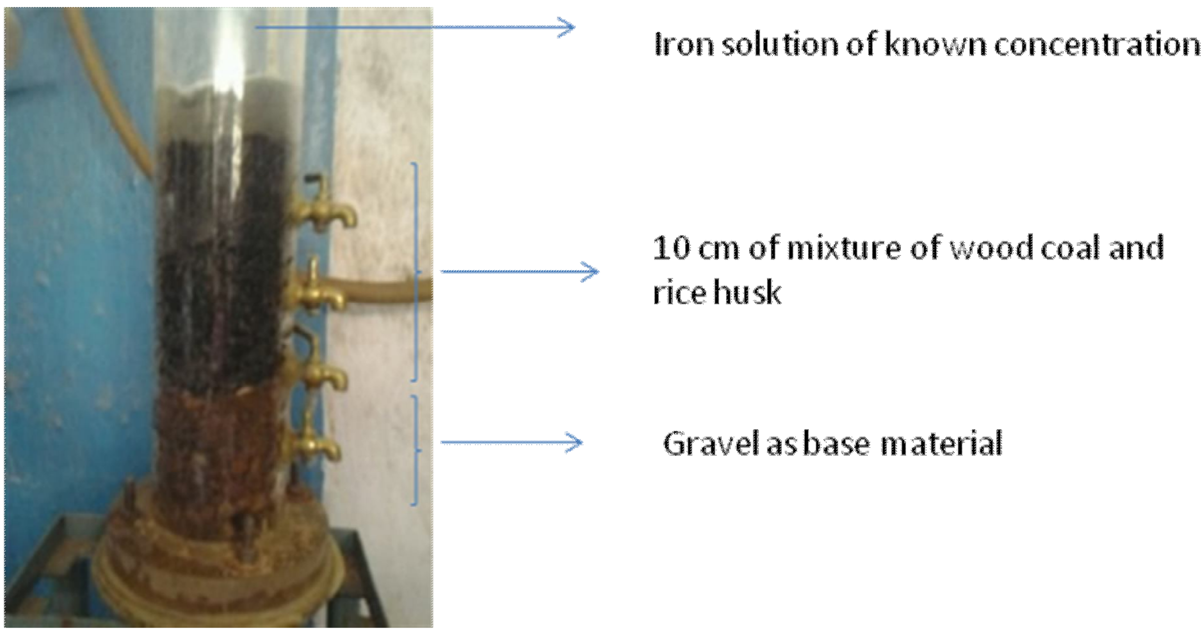
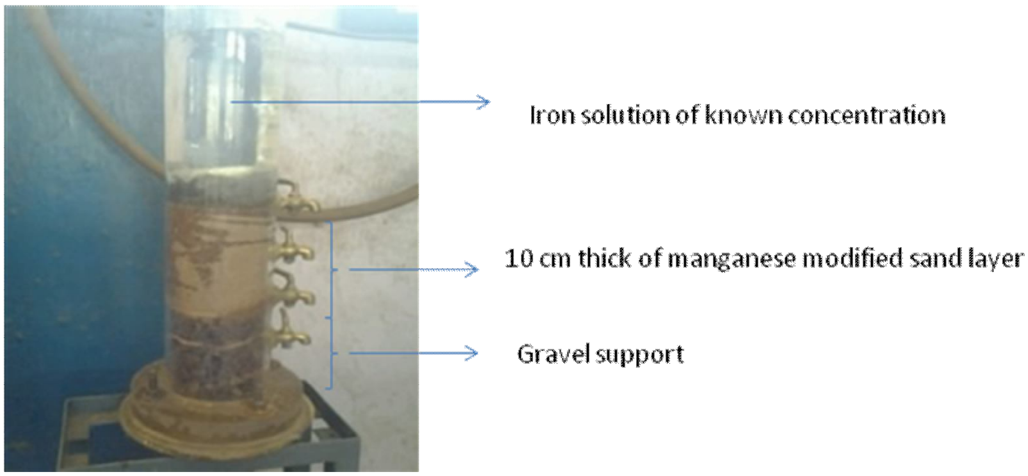


Fig 4.4 Filtration using wood charcoal and rice husk as adsorption media

Manganese modified sand

For removal of heavy metal ions, use of activated unsaturated sand filter (AUSF) being the most common technique [8]. Naturally occurring manganese oxide tend to attenuate some heavy metals, silt, sediment, due to its good sorptive capacity towards the ions such that copper, iron, arsenic etc due to high specific surface, micro pores available on its surface, possession of –OH functional group which leads to strong chemical bonding with some metal ions [9].



, Fig 4.5 Filtration by manganese modified sand

Aluminum hydroxide coated Rice husk ash

This adsorption media has been previously used for defluoridation of drinking water where the hydrolysis of aluminum sulphate in alkaline medium produces polyhydroxy aluminum precipitate which forms a complex with fluoride ions in water [12, 13]. Here without making any change to the active surface of RHA coated with Al(OH)3, the adsorption media has been tested for efficiency in removal of iron instead of fluoride. For experimentation 1000 ml of iron solution of known concentration was taken and the filtered water was collected after filtration and the rate of filtration was noted.

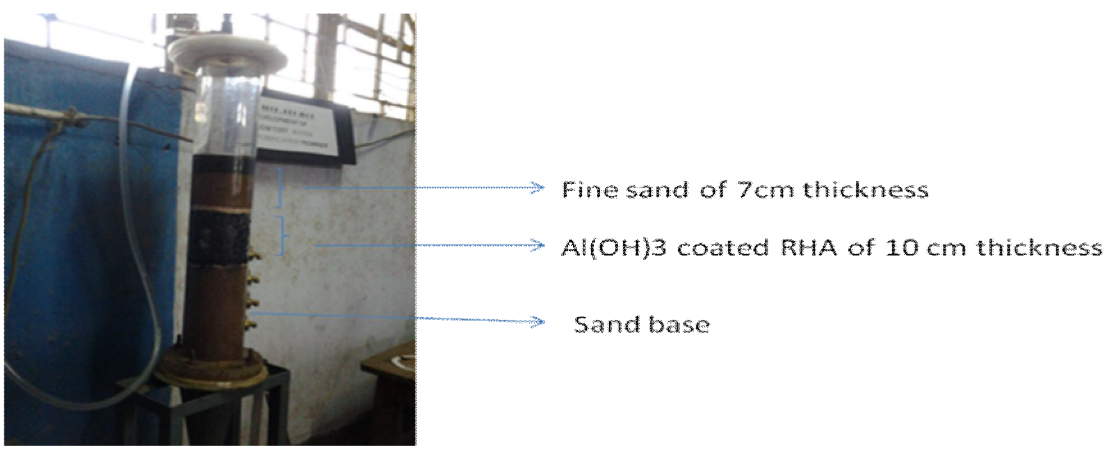


Fig 4.6 (a) Rice husk ash prepared after controlled heating at 500 degrees, (b) RHA soaked with 0.01N HCl, (c) Al(OH)3 coated RHA, (d) Filtration with Al(OH)3 coated RHA

Here well graded anthracite grains as per mentioned in 3.26 i.e., of size 625 micron and down have been used as an adsorption media for removing iron. 15cm thickness of well compacted material was taken inside the filtration model and then 1000ml of iron solution of known concentration was passed through it and the filtered water was collected in a beaker whose iron concentration was measured by AAS. The time taken for filtration was noted.

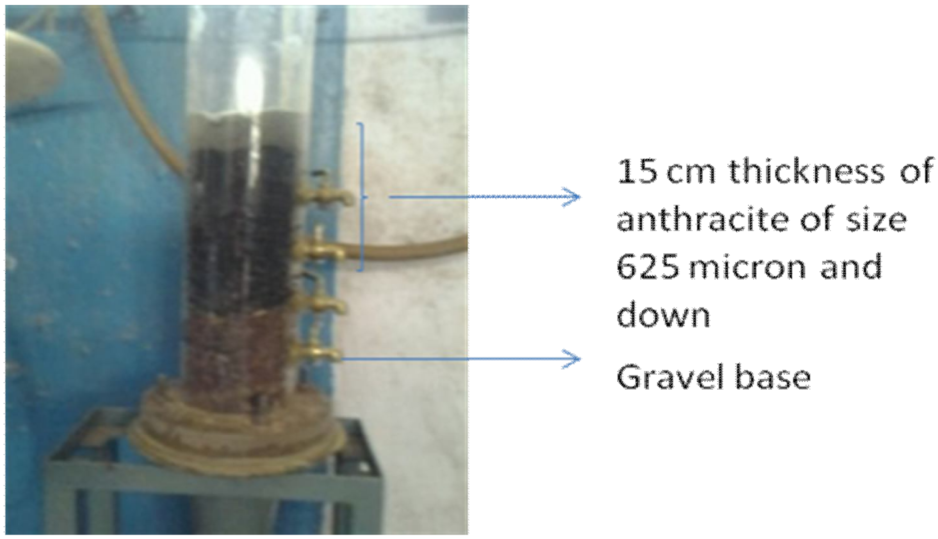


Fig 4.7 Filtration with anthracite

4.2 Oxidation and Precipitation

Before filtration of iron, it is needed to be oxidized to a state in which it can form insoluble iron complexes. By use of oxidizing agents, Fe^{2+} can be converted to insoluble Fe^{3+} which forms insoluble iron hydroxide complex $Fe(OH)_3$ [14]. Potassium permanganate, chlorine are the most abundantly used oxidizing agents. Here ash produced from banana leaf, stem and rind are being used as an oxidizing agent.

Ash obtained from banana rind, pseudo-stem and leaf are rich in potassium. Usually in ground water which is deprived of oxygen, the iron remains in soluble state. When ash is added to the water, it forms KOH from K_2O and K_2CO_3 present in the banana ash. So the medium becomes alkaline and at high pH, the soluble Fe^{2+} is converted to insoluble geothite (FeOOH) or ferrihydrite ($Fe(OH)_3$) [15, 16, 17]. And the precipitate can be filtered using any convenient filter media.

The material is the mixed with sample water of 5 PPM iron solution in presence of air and the floc of ferric hydroxide was precipitated. The water was filtered by a filter paper after 30 min of addition.

4.3 Microfiltration

Here the ceramic filter as mentioned in 3.29 was inserted inside the mould and the mould was kept inside a glass jar in which filtered water will be stored. Ceramic filter was tested for removal of turbidity and for experimentation 1000ml of solution of known turbidity was passed through the filter and then the filtered water through the pores of ceramic filter was collected in the mould having porous base and finally inside the glass jar. Then the filtered water was collected by the tap in a beaker and tested for final turbidity and the time taken for filtration was noted for calculation of rate of filtration.

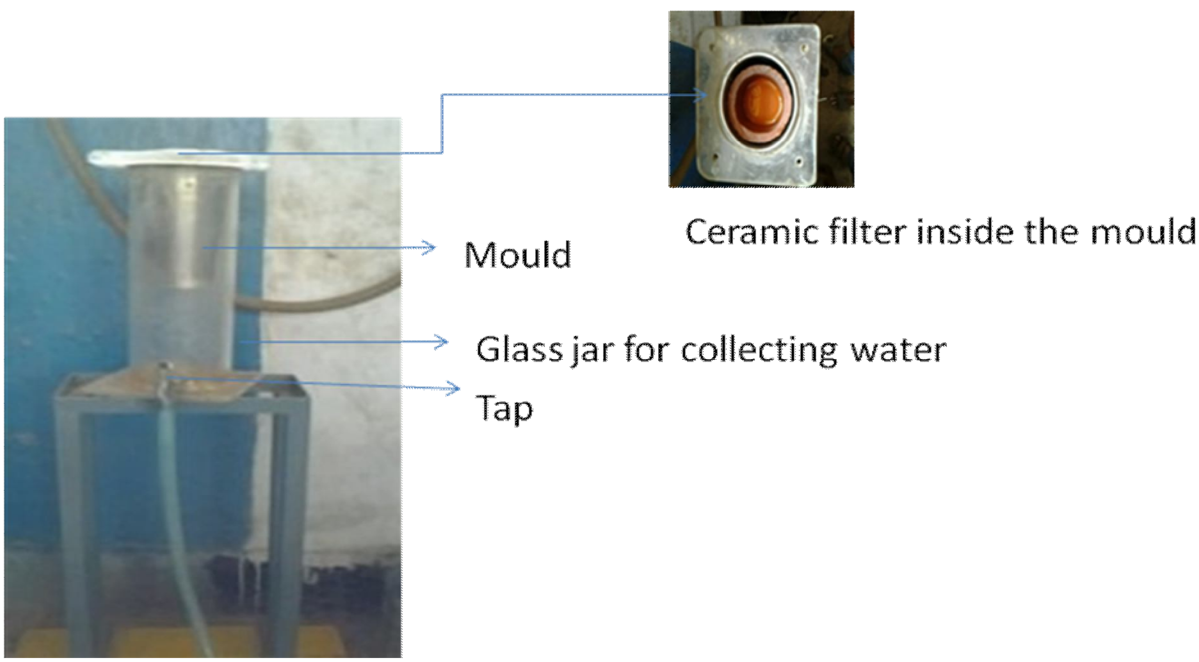


Fig 4.8 filtration of turbid water by ceramic filter

Chapter 5

Result and Discussion

5.1 Results obtained for Adsorption Process

The following results are obtained in removal of iron by using different adsorption media as mentioned in 4.1. The rate of filtration and the effectiveness in removing iron are tabled here.

Sand media

The initial iron concentration was 5.208 PPM in case of 425 micron sand and after filtration the final concentration was found to be 0.17 PPM by averaging the three sample results. Similarly in case of sand of size 600 micron the iron concentration reduced from 5.211 PPM to 0.386. The rate of filtration in case of sand of smaller size was lesser due to smaller pore size and larger specific area which increased the surface for adsorption.

Table 5.1 Results of filtration in sand media

Size of sand (micron)	Sample no.	Initial Iron content (PPM)	Final Iron Content (PPM)	Rate of filtration (ml/min)
425	1	5.208	0.142	333
	2		0.144	333
	3		0.222	333
600	1	5.211	0.36	500
	2		0.41	500
	3		0.39	500

Activated Carbon

As per 3.22, due to crushing of the activated carbon, the specific surface for adsorption may be increased, but the pore size increases. So there was not so significant removal of iron. Activated carbon for removal of iron should be separately fabricated instead of using the used carbon filter for better iron removal as well as removal of other impurities. The result obtained for activated carbon is given below.

Table 5.2 Results of filtration in activated carbon media

Size of Activated carbon (mm)	Sample no.	Initial Iron content (PPM)	Final Iron Content (PPM)	Rate of filtration (ml/min)
2	1	10.008	5.42	6700
	2		5.144	6700
	3		6.222	6700

Wood charcoal

Similarly in case of wood coal as mentioned in 3.23 due to bigger size of coal, the rate of filtration was high but the removal of iron was not significant. For better removal the coal should be either crushed to smaller size or should be mixed with any other binder for reducing the porosity and increasing the filter effectiveness.

Table 5.3 Results of filtration in wood charcoal media

Size of Wood charcoal (mm)	Sample no.	Initial Iron content (PPM)	Final Iron Content (PPM)	Rate of filtration (ml/min)
10	1	10.286	5.61	5500
	2		5.64	5570
	3		7.286	5500

Charcoal and rice husk mixture

Due to use of raw rice husk as a filter media, the filtrate became turbid and degraded after 2days. So it was discarded from being used as a filter media.

Manganese modified Sand

Surface Morphology Analysis

The SEM images showed that the uncoated sand has fairly uniform surface with small fractures giving a slight rough surface. In contrast, due to new born coating the coated sand appears to be somewhat rougher at the same magnification. These new developed surfaces may be proved to be a good adsorbent surface for iron removal.

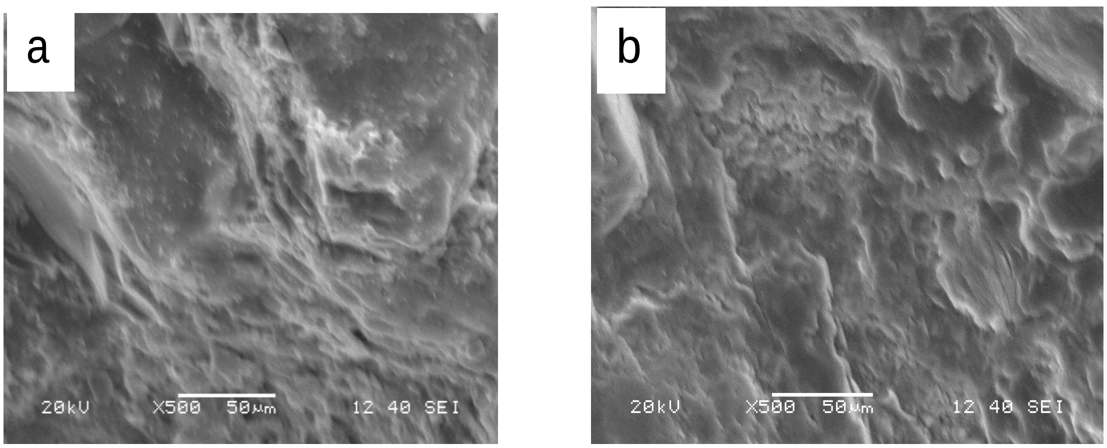


Fig 5.1(a) SEM image of uncoated sand, (b) SEM image of Manganese modified sand with 500 x magnifications

Due to surface activation the specific surface area of manganese modified sand was increased and iron removal was very significant from initial concentration of 5.262 PPM to 0.1 PPM by taking average of the three samples. In the second sample the final negative iron concentration indicated complete removal of iron.

Table 5.4 Results of filtration in manganese modified sand media

Size of sand (mm)	Sample no.	Initial Iron content (PPM)	Final Iron Content (PPM)	Rate of filtration (ml/min)
	1		0.26	125
850	2	5.262	-0.018	170
	3		0.041	125

Al(OH)3 coated Rice husk ash

Here after filtration, the chemical analysis of the aluminum hydroxide coated RHA was not done which could have gave a proper reason of removal of iron from the water by activated RHA. Still it gave quite satisfactory result in removal of iron. The final iron concentration was averaged to be 0.49 PPM. The rate of filtration was also calculated and given in table below.

Table 5.5 Results of filtration in Al(OH)3 media

Size of RHA (mm)	Sample no.	Initial Iron content (PPM)	Final Iron Content (PPM)	Rate of filtration (ml/min)
425	1	5.251	0.561	140
	2		0.25	140
	3		0.659	140

Anthracite

Here anthracite [1] was proved to be a good adsorbent for removal of iron and the iron removal was from 5.785 PPM to 0.79 PPM by averaging the concentration of three samples. The rate of filtration was calculated and given in the table.

Table 5.6 Results of filtration in anthracite media

Size of anthracite (mm)	Sample no.	Initial Iron content (PPM)	Final Iron Content (PPM)	Rate of filtration (ml/min)
625	1	5.785	0.533	330
	2		1.606	330
	3		0.231	330

5.2 Results obtained from Oxidation-precipitation by ash from banana residue

After filtering the precipitate from 50 ml of iron solution, the final iron concentration of filtered water was measured by AAS and the removal of iron was very efficient due to oxidation of iron in alkaline medium as compared to adsorption process. The result of filtration by oxidation is given below.

Table 5.7 Results of filtration by oxidation and precipitation using banana ash

Material	Amount (gm/50 ml)	Initial iron content (PPM)	Final iron content (PPM)
Ash from leaf	3	5.785	0.016
Ash from rind	3	5.785	0.248
Ash from stem	3	5.785	0.361

Despite of being the most effective in removal of iron, the ash production of banana leaf was very less as compared to the banana rind and stem. So we took mixture of ash of banana rind and stem in 1:1 ratio and added different amount of mixture in 50 ml of iron solution of known concentration and final iron content was measured and a graph was plotted with Iron content in X-axis and amount of ash added in 50 ml of solution in Y-axis. The graph showed that with increase in amount of ash added, the iron concentration was gradually decreasing and finally attaining negative values which indicate complete removal of iron from solution.

Table 5.8 Results obtained for iron removal by using 1:1 mixture of ash from banana rind and banana stem

Amount of mixture (gm/50 ml)	Initial iron content (ppm)	Final iron content (ppm)
3	5.785	0.299
5	5.785	0.17
10	5.785	0.139
15	5.785	0.016
20	5.785	-0.019
50	5.785	-0.001

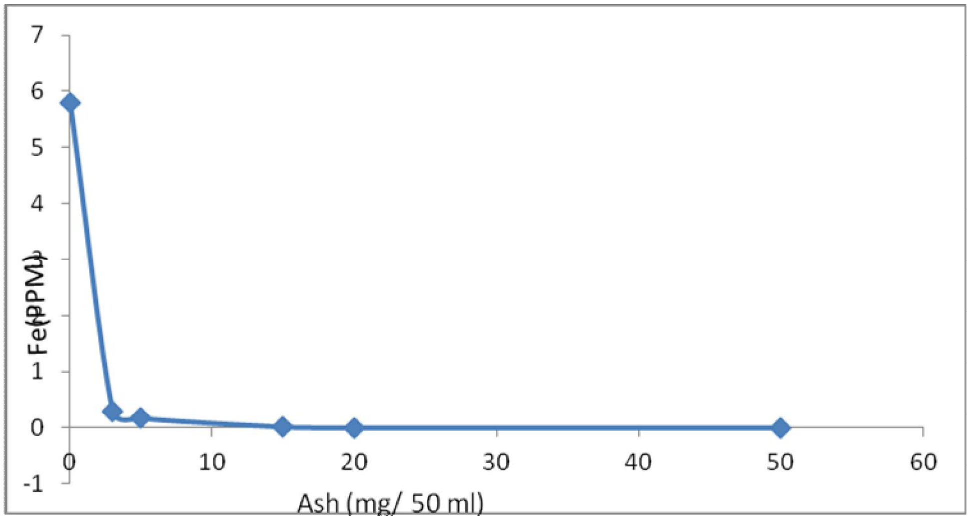


Fig 5.2 Concentration of iron ion versus amount of ash mixture in mg/ 50 ml of iron solution

5.3 Results obtained from ultra filtration by Ceramic filter

Due to use of 425 micron size rice husk, the pore size of the ceramic filter was slightly bigger to trap very fine suspended particles. So the removal of turbidity is not very efficient. For better filtration, the size of rice husk should be about 75 micron similar to the size of clay used as mentioned in 2.29. By introducing active sand and active RHA, the removal efficiency was increased which is shown in the table.

Table 5.9 Filtration using ceramic filter for removal of turbidity

Material	Initial turbidity (NTU)	Final turbidity (NTU)	Rate of filtration (ml/min)
Only ceramic filter	13.5	5.3	0.476
Half filled with MMNS	13.5	2.53	0.277
Half filled with RHA	13.5	3.46	0.222
1:1 ratio of MMNS & RHA	13.5	1.23	0.167

5.4 Cost of the filter used

Here we have provided a crude chart for the cost of all the adsorbent media we have used for experimentation excluding the labor cost, maintenance cost and energy cost.

Table 5.10 cost of ceramic filter used per cm3

Sl. No.	Ingredient	Percentage by weight	weight in kg	Unit price / kg in Rs.	Cost (rupees)
1	Clay	46.67	0.4	0	0
2	Sod. carbonate	3	0.0175	250	4.375
3	Sod. metasilicate	1.5	0.00855	310	11.2
4	Boric acid	1.5	0.00855	460	3.91
5	Rice husk	23.34	0.2	20	4
					Total= 23.6 /filter volume= 23.6/11.78 cm3= 2rupess/ cm3

Here the material cost of each adsorption media per kg used for experimentation is given in the table and the total cost as per the amount of material used is also mentioned. From the table, it is clear that ash from banana residue is with minimal cost and maximum efficiency in removing iron.

Table 5.11 Material cost of different adsorbent media used in experimentation

Material	**Amount used for experiment (kg)**	**Rate per kg In rupees**	**Total cost In rupees**
sand	0.6	15	9
Reused Activated carbon	0.4	20	8
Charcoal	0.2	10	2
Rice husk	0.3	20	6
Anthracite	0.6	330	198
KMnO4	0.037	150	5.5
Banana ash	0.1	10	1
Aluminum sulphate	0.054	20	2

Chapter 6

CONCLUSIONS

- Adsorption being the simplest and cheapest technique for iron removal, it has several advantages, like longer filtration runs, shorter ripening time, better filtrate quality. But the only limitation is back wash water requirement is essential for the filter media to run effectively.

- Sand being the cheapest adsorbing surface is very effective in removal of dissolved iron from drinking water and the rate of filtration is also very high. The only demerit is subsequent development of bacterial layer due to rigorous use. Again back washing is needed time to time.

- In case of activated carbon and wood charcoal, the removal is not so significant. This may be due to lager particle size of material being used. Smaller the size of particle larger will be the specific surface and better will be the removal.

- The SEM images showed that the uncoated sand has fairly uniform surface with small fractures giving a slight rough surface. In contrast, due to new born coating the coated sand appears to be somewhat rougher at the same magnification. These new developed surfaces proved to be a good adsorbent surface for iron removal. There is negative concentration of iron after filtration signifies no traces of iron in water.

- Aluminum hydroxide coated RHA also proved to be a good adsorbent in removal of iron. Previously it has been experimented that it forms complexes with fluoride ion for its removal. Here in case of iron, there is no proof of formation of any complex. So the removal may be credited to roughening of RHA surface due to modification by aluminum hydroxide.

- Banana ash has been proved to be effective enough for removal of iron ion and being the cheapest material used in the experiment. The production of banana ash is also very cost effective where it is only burned by controlled combustion at 500 degree Celsius for 4 hours. But only some manual mixing is required for filtration when large amount of water is supposed to be filtered. By a simple cotton cloth the filtered water can be separated.

- Ceramic filter used in the experiment is also very cost effective. The cost of the membrane is given below. The only difficulty is rate of filtration is very slow as water is filtered under gravity. Due to frequent use of the ceramic filter some cracks developed on its surface which is undesirable. The size of rice husk used in the filter regulates the rate and effectiveness of the filtration. The size of RH used was 425 micron, if the size could have even smaller then the pore size also could be reduced and enhancing the quality of filtrate but reducing the rate of filtration.

Chapter 7

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