Preparation of filters for water purification using rice husk ash

Thesis submitted in partial fulfillment for the requirement of degree of

Master of Technology
In
Environmental Science and Technology

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JULY 2013

DECLARATION & CERTIFICATE

I hereby declare that the work embodied in thesis entitled **"Preparation of filters for water purification using rice husk ash"** for the award of degree of Master of Technology submitted in the **"School of Energy And Environment"**, Thapar University, Patiala in July 2013, is a record of the work carried out by me under the guidance of **Dr. Amit Dhir** Assistant Professor, School of Energy and Environment. The matter presented in this thesis has not been submitted in part or full, to this or any other University/Institute for any degree or diploma.

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It is certified that the above statement made by the student is correct to the best of my knowledge and belief.

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ACKNOWLEDGEMENT

It is matter of immense pleasure to acknowledge my debt to my revered teacher and Supervisor **Dr. Amit Dhir,** Assistant Professor, School of Energy and Environment, Thapar University, Patiala. It is because of his priceless intellectual guidance, innovative and constructive ideas for having given me complete independence, affectionate encouragement to put my desire and thought, which paved the way for the successful completion of this seminar. I would like to thank him for giving me the opportunity to work on this project.

I also feel very much obliged to **Dr. A.S. Reddy**, Head, School of Energy and Environment Thapar University, Patiala for his kind cooperation and encouragement which helped in the completion of this work.

I am thankful to **Mr. Tanuj Chopra**, Assistant Professor for his help, support & valuable hints.

I would like to thank my class mate Nikita Rajpal for her constant help and motivation at various stages of my thesis. The generous support of all the staff members of School of Energy and Environment and Department of Biotechnology is greatly appreciated.

Last, but not least, I thank **God** for giving me strength to overcome difficulties encountered.

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ABSTRACT

The ground water supplies have become highly contaminated by the addition of undesirable substances that have rendered it unfit and toxic for various purposes, especially for drinking. The main ground water quality problems in India are due to salinity, arsenic, nitrates, fluorides, uranium, heavy metals, oils, etc whereas the discharge from industries is also polluting the water as it is high in salinity, heavy metals and other impurities. India is primarily an agriculture-based country and its economy largely depends on agriculture. It is one of the world's largest producers of white rice, accounting for 20 % of all world rice production. Rice milling industry generates a lot of rice husk during milling of paddy. During this process about 78 % of weight is received as rice, broken rice and bran. Rest 22 % of the weight of paddy is received as husk. This husk is used as fuel in the boilers to generate steam for heating and power generation. This husk is converted into ash during the firing process which is termed as rice husk ash (RHA). RHA is of great environmental concern because of its detrimental effects to the land and the surrounding area in which it is dumped. In order to combat the problem of water pollution and disposal of RHA, the use of RHA has been explored in making of filters which are used for the treatment of water/waste water. The RHA based ball and column filter were prepared using different composition of RHA, cement and sand. Drying and curing were important part of the preparation process. The method for optimization of contact time and composition was followed and the treatment efficiency was determined. The main focus was on the reduction of TSS, TDS, turbidity and concentration of chlorides and sulphate from water samples collected from various locations by using RHA based filters. The observations indicate that the ball filters were better in TDS and TSS removal than column filter. The optimum time for reduction of TDS from water samples was reported to be 4 h and the optimum composition of ball filter was found to be 100 g cement, 50 g sand and 50 g RHA for water and wastewater purification. The RHA based ball filter showed up to 88% reduction in TSS, up to 43 % TDS reduction and reduction in concentration of chloride up to 47% for waste water. The mild reduction in sulphate concentration was also reported. When the silica content was reported to be 11.3 mg/l from 11.1 mg/l after 6 h of treatment with RHA based ball filter in the ground water sample from Patiala. Upto 60% reduction in turbidity was observed in case of industrial sample which had high level of turbidity before treatment. An experiment to determine the repeatability and reusability of ball and column filter was conducted and it was observed that the ball filter showed about 10% efficient after 10 cycles of treatment whereas the efficiency of column filter came out to be 5%

just after 4 cycles of treatment. So, the results conclude that the utilization of rice husk ash in the making of ball filters for the treatment of drinking water and industrial wastewater has been found to be efficient.

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CHAPTER-1

INTRODUCTION

Water is one of the universal substances, which is used alike by all the living species to sustain life. Clean and plentiful water provides the foundation for prosperous life and communities. We rely on clean water to survive, but now we are heading towards a water crisis. The changes in climatic patterns are threatening lakes and rivers, and also the key sources that we tap for drinking water, which are being overdrawn or tainted with pollution. Moreover, Industrialization activities for the development of nation contribute to global environmental deterioration as these activities caused depletion, degradation and deterioration of natural resources and biodiversity. Additionally, these industrial activities indirectly overload water body with thousands of water pollutant and subsequently polluting the environment.

1.1 Overview of the problems related to ground water

Basic domestic water quantity needs can be divided into categories including water for drinking, cooking, hygiene, and other domestic purposes, including productive uses. Drinking water comes from surface and ground waters. Large-scale water supply systems rely on surface water resources, and smaller water systems use ground water [*Singh et. al., 2003*]. Drinking water needs can vary according to the water content of food consumed, manual labor performed and climatic conditions. In addition, men, children and women have varying needs. The ground water supplies have become highly contaminated by the addition of undesirable substances that have rendered it unfit and toxic for various purposes, especially for drinking. The quality of groundwater is generally slower to change, especially when it comes from deeper aquifers. The groundwater is not directly exposed to wastewater discharge, air pollution, or contamination from run-off (if the well is properly constructed).Natural filtration can remove some contaminants as the water percolates through the soils and rock thus protecting the quality of ground water.

Safe drinking water is essential for living; lack of access has resulted in many water related diseases. There are an estimated 4 billion cases of diarrhoea annually [*WHO, 2009b*]. Despite being largely preventable and treatable, every year 1.8 million people die from diarrhoeal diseases [*WHO, 2009a*]. Eighty-eight percent (88%) of these deaths are attributed to unsafe water supply, inadequate sanitation and poor hygiene [*WHO, 2009a*].

According to UNICEF's report ‘‘Fresh water for India's children and nature’’, nearly 1 million children in India die of diarrhoeal diseases each year directly as a result of drinking unsafe water and living in unhygienic conditions [*Saint, 1995*]. Table 1.1 shows the various land-use activities and the threat they cause to the ground water quality [*CPCB, 2007*].

Table1.1: Land-use activities and their potential threat to ground water quality

Land use	**Activities potential to ground water pollution**
Residential	• Un-sewered sanitation • Land and stream discharge of sewage • Sewage oxidation ponds • Solid waste disposal, sewer leakage , landfill leachate • Road and urban run-off, aerial fall out
Industrial & Commercial	• Process water, effluent lagoon etc. • Land and stream discharge of effluents • Tank and pipeline leakage and accidental spills • Well disposal of effluent • Aerial fall out • Landfill disposal and solid wastes and Hazardous wastes • Poor housekeeping • Spillage and leakage during handling of material
Mining	• Mine drainage discharge • Process water and sludge lagoons • Solid mine tailings • Oilfield spillage at stations
Rural	• Cultivation with agrochemicals • Irrigation with wastewater • Soil Stalinizations • Livestock rearings
Coastal areas	• Soil water intrusions

In general, greater part of the India, ground water is used for agricultural, drinking or industrial purpose. The ground water in shallow aquifers is generally suitable for use for different purposes and is mainly containing calcium carbonates and bicarbonates. The quality in deeper aquifers also varies from place to place and is generally found suitable for common uses.

The main ground water quality problems in India are salinity, arsenic, nitrates, fluorides, etc. Salinity in ground water can be of broadly categorized into two types, i.e. Coastal Salinity and Inland salinity. Inland salinity in ground water is prevalent mainly in the arid and semi arid regions of Punjab, Rajasthan, Haryana, Gujarat, Delhi, Uttar Pradesh, Andhra Pradesh, Maharashtra, Tamil Nadu and Karnataka. There are several places in Rajasthan and southern Haryana where Electrical Conductivity (EC) values of ground water is greater than 10000 mS /cm at 25^{o} C making water non-potable [*CGWB, India*]. In some areas of Gujarat and Rajasthan, salinity in ground water is so high that the well water is directly used for salt manufacturing by solar evaporation. Inland salinity is also caused due to practice of surface water irrigation without consideration of ground water status. High concentration of fluoride in ground water beyond the permissible limit of 1.5 mg/l poses some of the health problems. The occurrence of arsenic in ground water was first reported in 1980 in West Bengal in India. The occurrence of Arsenic in ground water is mainly in the intermediate aquifers up to the depth of 100m and the deeper aquifers are free from contamination of arsenic. Apart from West Bengal, contamination of arsenic in ground water has been found in the states of Bihar, Chhattisgarh, Punjab, Uttar Pradesh and Assam. Arsenic in ground water has been reported in 15 districts in Bihar, 9 districts in U.P and one district each in Chhattisgarh & Assam states [*CGWB, India*]. Quite high concentration of Iron (>1.0 mg/l) in ground water has been observed in more than 1.1 lakh habitations in the country. Iron contamination in ground water has been reported from the states of Assam, Andhra Pradesh, Bihar, Chhattisgarh, Gujarat, Goa, Haryana, J&K, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Meghalaya, Manipur, Maharashtra, Orissa, Punjab, Rajasthan, Tripura, Tamil Nadu, Uttar Pradesh, UT of Andaman & Nicobar and West Bengal. Nitrate is a very common constituent in the ground water of shallow aquifers. The main source is from the anthropogenic activities. High concentration of Nitrate in groundwater beyond the permissible limit of 45 mg/l poses health problems.

The Punjab State is mainly underlain by quaternary alluvium of considerable thickness, which is next against the rocks of Siwalik system towards North-East. The presence of salt impregnated strata below these soils is responsible for the poor quality of underground water in some of the areas of Punjab. The southwest part of Punjab comprising 34 per cent of area faces severe groundwater quality problems that prevent its withdrawal from source. In this region, the salinity, alkalinity or both are responsible for the poor quality of groundwater. For a long time access to clean drinking water has remained a big problem for people of Punjab.

High values of uranium (more than 9 mg/1) present in drinking water may lead to harmful biological effects in humans. The chemical toxicity of natural uranium is a major hazard to the kidneys [*Lussenhop et al., 1958*]. In Punjab, it has been reported that uranium concentrations in the groundwater samples from hand pumps/shallow tube wells are in general high wherever the leftover residue (Total Dissolved Salt) after drying of water is high ~ 2-7 g/L, pesticides and herbicides are also reported to be high [*CGWB,Punjab*].

Arsenic in ground water is largely the result of minerals dissolving from weathered rocks and soils. The underground waters contain elevated arsenic concentration, which are usually above the WHO (1996) permissible safe limits of 10 ppb [*Hundal et al., 2007*]. The problem is more severe at several sites in south-western districts of Punjab where the arsenic concentration exceeded more than 20 to 30 folds of the WHO safe limit. The world health organization and US Environment Protection Agency recently established a new maximum contaminant level of 10 ppb in drinking water for arsenic. The arsenic concentration of deep water tube wells located in Amritsar city used for domestic supply for population in urban areas ranged from 3.8 to 19.1 ppb with average value of 9.8 ppb. The content of arsenic in hand pump water varied from 9 to 85 ppb with a mean value of 29.5 ppb [*Hundal et al., 2008*]. Arsenic has been known to cause a variety of adverse health effects which includes skin and several internal cancers and cardiovascular and neurological effects [*Murphy et al,. 1981; Wu et al., 1989; Smith et al., 1992; Chiou et al., 1995; Mandal et al., 1996; Lynda et al., 2006*].

High Concentration of Fluoride (>1.5mg/l) has been reported in Amritsar, Bhatinda, Faridkot, Firozepur, fatehgarh Sahib, Gurdaspur, Muktsar, Moga, Patiala, Sangrur districts of Punjab. High Chloride content (>1000mg/l) has been observed in Firozepur and Muktsar. Chloride contributes to osmotic activity of body fluids. Elevated levels of chloride may impart a noticeable salty flavour to water, but the threshold depends upon the associated cations.

Iron content >1.0 mg/l has been reported in Bhathinda, Faridkot, Firozepur, Fatehgarh Sahib, Hoshiarpur, Gurdaspur, Rupnagar, Mansa, Sangrur districts. Nitrate occurs in water supplies as a result of decomposition of organic matter from excessive use of fertilizers and contamination by surface drainage. The high levels of nitrate in water samples may cause stomach cancer in human beings. High level of Nitrate (>45 mg/l) has been reported in several districts of Punjab. Table 1.2 shows the permissible limits for various parameters and their undesirable effect they cause when they exceed the limit.

Table 1.2: Indian standards for drinking water

S. No	**Parameter**	**Requirement (Desirable limit)**	**Undesirable effect beyond the desirable limit**	**Permissible limit in the absence of alternate**
1	Fluoride	Max 1.0 mg/l	Fluoride should be kept as low as possible as the high fluoride may cause fluorosis	1.5 mg/l
2	Chlorides	Max 250 mg/l	Corrosion and palatability are effected beyond this limit	1000 mg/l
3	Dissolved solids	Max 500 mg/l	Palatability decreases and may cause gastro intentional irritation beyond this limit	2000 mg/l
4	Sulphate	Max 200 mg/l	Outside the permissible limit causes gastro-intestinal irritation when magnesium or sodium are present	400 mg/l
5	pH	6.5 – 8.5	The water will affect the mucous membrane and / or water supply system beyond this range	No relaxation
6	Turbidity	Max 5 NTU	Above 5, consumer acceptance decreases	10 NTU

The Salinity, EC>3000 µS/cm at 25° C, has been reported in the Ferozepur, Faridkot, Bathinda, Mansa, Muktsar, Sangrur districts [*CGWB*, *Punjab*]. The sulphate ranges between 10mg/l at Bhagi Bhandar and 480mg/l at Dadde(Bhatinda district). In majority of ground water samples, the concentration of sulphate is below 400mg/l and its average concentration in the district is 201mg/l. The sulphate content varies widely and ranges from 13 mg/l at Dhak Raba to 1174mg/l at Antala(Patiala district) [*Water Quality Assessment Authority*].

Total Dissolved Solids measures the solids remaining in a water sample filtered through a 1.2 µm filter. According to the World Health Organization [*WHO*, *1996*], the compounds and elements remaining after filtration are commonly calcium, magnesium, sodium, potassium, carbonate, bicarbonate, chloride, sulfate, silica and nitrate-n. High TDS affects the taste and odor of water and in general, levels above 300 mg/L become noticeable to consumers. As TDS increases, the water becomes increasingly unacceptable. Although the SMCL for TDS is 500 mg/L, levels above 1200 mg/L are unacceptable to most consumers. Because TDS measurements may include a variety of parameters which can be naturally occurring or anthropogenic, its value as an indicator of nonpoint source pollution is limited.

1.2 Overview of the problems related to wastewater

Industrial waste constitutes the major source of various kinds of metal pollution in natural water. Wastewaters generated from industrial treatment plant contain considerable metal contaminants. Their concentrations must be reduced to safe levels before being released into the environment. Rapid industrialization has led to increase disposal of heavy metal into the environment. Pollutants in industrial wastewater are almost invariably so toxic that wastewater has to be treated before its reuse or disposal in water bodies. Major importance has been attached to the treatment of industrial wastewater effluent since local and international authorities require that wastewaters from industries be treated and made to meet a set standard before it is discharged into the water bodies. The conventional wastewater treatment processes are expensive and require complex operations and maintenance. It is estimated that the total cost for establishing treatment system for the entire domestic wastewater is around Rs. 7,560 crores [*CPCB, 2005a*], which is about 10 times the amount which the Indian government plans to spend [*Kumar, 2003*]. One of the major problems with wastewater treatment methods is that none of the available technologies has a direct economic return. Due to no economic return, local authorities are generally not interested in taking up wastewater treatment. So, there is a need of safe and economical methods for the elimination of heavy metals from contaminated waters. This need has developed interest towards the production of low cost alternatives to commercially available adsorbent. So there is an urgent need that all possible sources of agro-based inexpensive adsorbents should be explored.

1.3 Treatment technologies

Several treatment techniques have been used for the treatment of groundwater so as to make it suitable for drinking purpose. These are ultra-violet (UV) treatment, reverse osmosis filters, slow sand filters, activated carbon and ceramic filters. UV treatment is a disinfection process that inactivates harmful microorganisms. UV treatment is not intended to treat water that is contaminated and this treatment is also expensive. Reverse Osmosis (RO) water filters are typically used to improve drinking and cooking water quality in households system. RO water filters are one of the finest water filtration methods which reduce almost all organic and inorganic chemicals, microorganisms, bacteria, metals, salt, and particulates that are found in contaminated water. It also improves tastes, odor and appearance but the cost of treatment is high due to requirement of change of membrane and also the disposal of reject water containing high TDS is a problem. Pre filters also need to be changed at least annually [*Chan et al., 2009*]. Unlike all the other water filtration methods, the slow sand water filters utilize biological processes in a non-pressurized system to purify water. Slow sand filters are effective at removing heavy metals, and it is often combined with activated carbon to remove organic material as well as to improve odor and taste but these can only filter water up to a certain turbidity level, as water with high turbidity clogs up the filter bed quickly. Activated carbon is processed carbon with a slightly positive charge added to it and is more attractive to chemicals and impurities. It is extremely-porous, thus provides high surface area to volume ratio which increases the rate of absorption [*Chan et al., 2009*]. Because of this property, activated carbon is commonly used in water treatment systems. The activated carbon can be used to improve odors and tastes alone, and also it is most effective at removing organic compounds including VOCs, radon, and chlorine but they are ineffective in removing bacteria and viruses. Ceramic filter is one of the most economical filtration methods and it is already being widely used in some third world countries [*Rayner, 2009*]. Ceramic filter blocks anything larger than a water molecule, allowing only water to pass through the pores.

1.4 Rice husk ash production and associated problems

Rice production is an important part of the national economy in India. It is one of the world's largest producers of white rice, accounting for 20% of all world rice production. In India rice is preeminent crop and staple food of the people of the eastern and southern parts of the country. Rice milling industry generates a lot of rice husk during milling of paddy which comes from the fields. During milling of paddy about 78 % of weight is received as rice, broken rice and bran. Rest 22 % of the weight of paddy is received as husk. This husk is used as fuel in the mills to generate steam for the heating applications. This husk contains about 75 % organic volatile matter and the balance 25 % of the weight of this husk is converted into ash during the firing process, is known as rice husk ash (RHA). Rice husk is an agricultural waste, obtained from the rice mills after the separation of rice from paddy. It is mostly used as a fuel in the boiler furnaces of industries like paper, sugar, etc. to produce steam. The rice husk ash (RHA) is collected from the particulate collection equipment attached upstream to the stack of the rice husk-fired boilers. RHA is available in plenty and almost free of cost. This RHA in turn contains around 85 - 90% amorphous silica and small proportion of alumina, iron oxide, calcium oxide, etc [*Basha et al., 2003; Zemke et al., 2009*]. So for every 1000 kgs of paddy milled, about 220 kgs (22%) of husk is produced, and this husk is burnt in the boilers, to generate about 55 kgs (25%) of RHA. It is estimated that about 70 million tons of RHA is produced annually worldwide. This rice husk ash is a great environment threat causing damage to the land and the surrounding area in which it is dumped. In India about 20 million tonnes of RHA is produced annually. Huge amount of rice husk is produced in Punjab region and there is a problem of disposal of RHA so there is a need to look for the alternative use of Rice Husk Ash for environment-friendly purpose.

Adsorption is a fundamental process in the physiochemical treatment of wastewaters, a treatment which can economically meet today's higher effluent standards and water reuse requirements. Adsorption is a mass transfer process which involves the accumulation of substances at the interface of two phases, such as, gas– liquid, liquid–liquid, liquid– solid interface or gas–solid. The adsorbate is the substance being adsorbed and the adsorbing material is termed the adsorbent. The driving force for adsorption process is Surface affinity. Chemical reactivity, pH, surface area for adsorption per unit volume and reduction in surface tension is key parameter for adsorption. Adsorption is a sorption operation, in which certain components of a fluid phase, called solutes, are selectively transferred to insoluble and rigid particles suspended in a vessel or packed in a column. Adsorption is a separation process in which certain components of the fluid phase are transferred to the surface of the solid adsorbents. RHA has the potential to be used as an adsorbent, because of the presence of carbon and silica.

Table 1.3: Characteristics of Rice husk ash

S No.	Parameter	Value
1	Average particle size	412µm
2	Bulk density	175.3kg/m^3
3	Moisture content	1.1%
4	Volatile matter content	7.36%
5	Ash content	80.58%
6	Fixed carbon content	10.96%

1.5 Properties of RHA

The rice husk ash (RHA) has more than 92% by wt of silica with high porosity and large surface area, because it retains a cellular structure skeleton. The physical characterizations of rice husk and RHA have pointed out some properties such as the presence of functional groups (carboxyl, silanol, etc.) that make adsorption processes possible. The chemical composition of Rice husk ash is shown in Table 1.3 and the chemical composition of rice husk ash is given in Table 1.4 which shows that major component in rice husk ash as described earlier also, is silica , 1.5% alumina is present and rest are the minor components.

Table 1.4: Chemical Composition of Rice husk ash

S No.	Component	%
1	Silica(SiO_2)	92.1
2	Alumina(Al_2O_3)	.51
3	Iron oxide(Fe_2O_3)	.40
4	Calcium oxide(CaO)	.55
5	Potassium oxide(K_2O)	1.53
6	Manganese oxide(MnO)	0.08
7	Phosphorus pentaoxide(P_2O_5)	.36
8	Sulphur trioxide(SO_3)	.12

1.6 Application of RHA in water purification systems

Ceramic filter is one of the most economical filtration methods and common form of house hold water treatment and it is reported to be used in some third world countries [*Chan et al., 2009*]. Ceramic filter blocks anything larger than a water molecule, allowing only water to pass through the pores. Two styles of ceramic filters exist on the current market, pot and candle ceramic filters. Candle ceramic filters are sometimes filled with activated carbon to increase water purity. The flow rate of ceramic water filters are controlled by surface area and the amount of additives. Ceramic filters are made with clay and combustible additives, all materials are inexpensive and can be easily found. Ceramic filters are brittle and require high maintenance in comparison with candle filters [*Chan et al., 2009*]. Clay suitable for pottery production can be used for making filters; however, plasticity is particularly important as 50-60% non-plastic (burn-out) material is added to the clay. Clay should have an acceptable level of plasticity, rate of dry shrinkage, and after firing, acceptable rates of total shrinkage and absorption [*Rayner, 2009*]. Burn-out material, such as sawdust, rice husks, or other agricultural by-product is added to the clay to create the required porosity of the fired element, which affects the flow rate of the filters. The material can vary depending on local availability. Since sediments fill up the pores on the filter surface, they need to be cleaned regularly.

There are many variables in the design of candle filters which are considered to influence the flow rate and/or effectiveness of the filtering element including the type of clay (particle size, distribution, sand content and plasticity), the burn-out material (type and size, humidity of burn-out material), the clay to burn-out ratio, the amount of water added to the mixture, the manufacturing method (molded by hand, pressed, wheel thrown), drying time and conditions, firing temperature, size of the filtering element, capacity and the thickness of the filter [*Rayner,2009*]. Traditionally, colloidal silver has been applied to the ceramic filters after firing [*Napotnik et al., 2009*]. Water flowing through the ceramic filter is thus treated by a combination of physical filtration and silver disinfection. A colloidal silver solution is either painted on, elements are dipped in a silver solution, or colloidal silver is integrated into the filter mix prior to pressing and firing the filters. Silver is added to improve the microbiological effectiveness of filters. Colloidal silver, a suspension of silver nanoparticles, acts as a disinfectant but reduces the pore size and structure of the filter medium, that increases clogging which subsequently reduces flow rate. Silver nitrate is applied to filters instead of colloidal silver at some factories. Microbiological efficacy of filters painted with silver nitrate is reported to be comparable to filters with no silver nitrate applied. The amount of silver measured in effluent water should be below USEPA (United States Environmental Protection Agency) and WHO guideline values for silver (0.1mg/L), and therefore should not pose a risk to human health. The candle filter has also been reported to be efficient in bacterial trapping and turbidity reduction [*Prasad, 2002*].Fig 1.1 shows the various environment-friendly application of rice husk ash like in the removal of dye, humic acid, crude oil, diesel or fuel removal and heavy metals from wastewater, in soil stabilization. RHA can also be used in making concrete, bitublock wall etc.

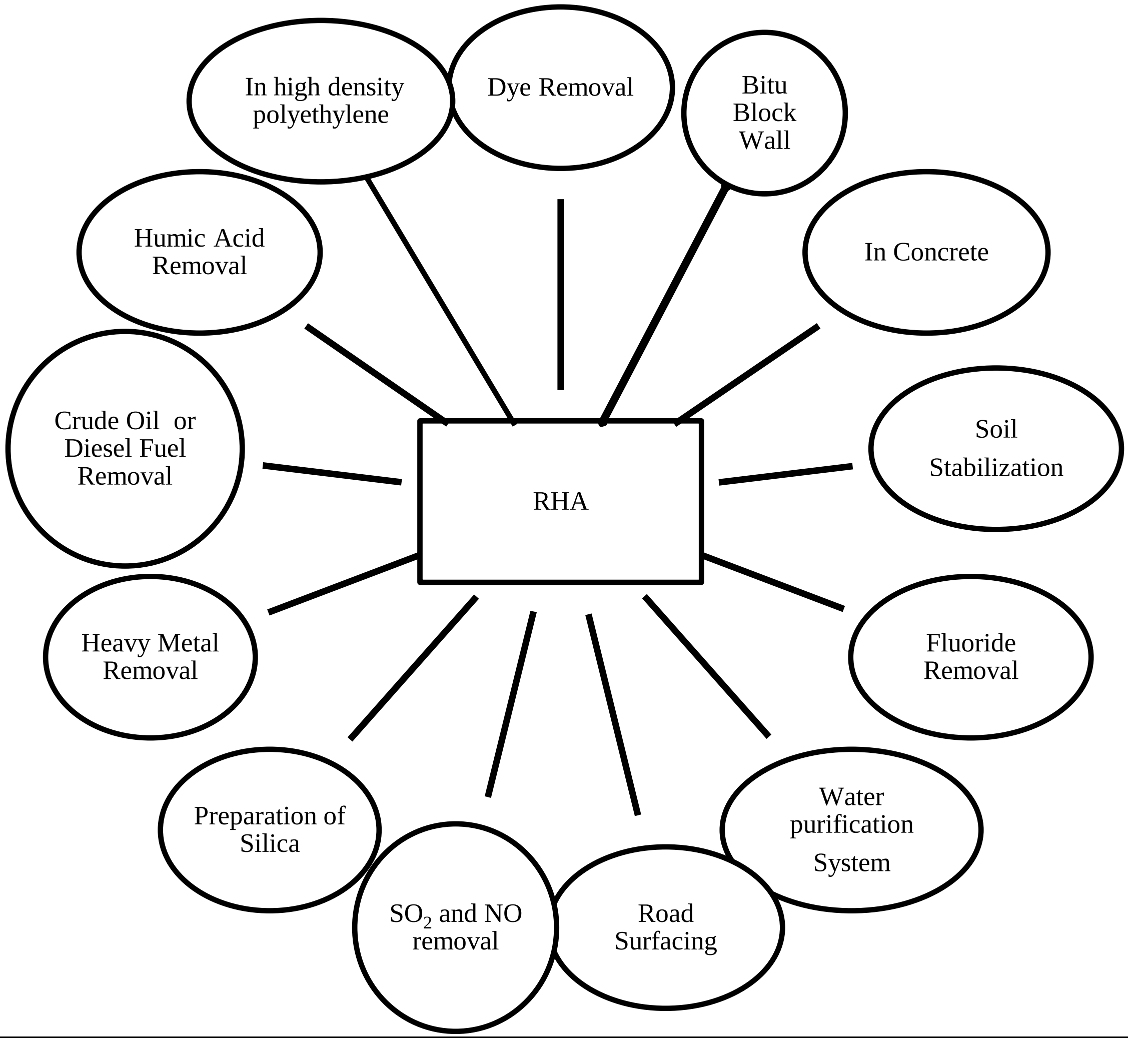

Figure 1.1 Applications of rice husk ash for environment-friendly purpose

In developing countries like India, the problems associated with ground water and wastewater reuse arise from lack of treatment. The challenge thus is to find such low-cost, low-tech, user friendly methods, which on one hand avoid threatening our substantial waste dependent livelihoods and on the other hand protect degradation of our valuable natural resources. The use of RHA for water and wastewater purification will be an efficient method as compared to the conventional treatment systems as it is environment-friendly, easily operated, low-construction, maintenance and operation cost and can be maintained by untrained personnel.

CHAPTER-2

REVIEW OF LITERATURE

Large quantity of RHA is produced all over the world annually. There is a problem of disposal of Rice husk ash and also it cannot be used for cattle feed. So there is a need to find alternatives to use RHA so that its disposal problem can be reduced. Rice husk ash can be used for variety of environment-friendly purpose like for the removal of dye, humic acid, crude oil, heavy metals, for concrete making, in construction of bitublock wall, in road surfacing, water purification system. The literature review gives the insight of the applications of RHA in water purification

2.1 Water purification systems

Prasad, 2002 made an attempt to prepare a low- cost water filter for which there is a definite need in rural India. He describes how even a simple- looking concept for water filtration has to go through several well-defined steps for successful introduction into the field. He used nylon membrane along with the concrete mixture of RHA, pebbles and cement to design a filter using sanitary pipes. He found out a considerable reduction i.e. 99% reduction in turbidity and bacteria when these filter was used for water purification in laboratory conditions. The filtered water, though not strictly of WHO standard for bacteria was expected to be useful in rural India considering the immunity level of the villagers.

Gavir et al., 2002 also prepared a similar type of filtration system using RHA except that he used perforated food grade plastic container instead of sanitary pipes which helped in the reduction of turbidity and bacterial count of water in rural areas**.** He also compared this design of filter with the candle filter and he concluded that the RHA based filter is cost effective than the ceramic candle filter. He concluded that RHA based filter was 25% more efficient in removal of bacteria and turbidity. Also, the filtration rate of RHA filter was greater than ceramic candle filters.

Chan et al., 2009 designed a low-cost and easily manufactured water filtration system for use in third world countries. He compared this filtration system with other conventional water treatment techniques. By using different agricultural waste for designing a filter, he compared the flow rate, different nutrients present in water like nitrate, nitrite and total phosphorus and the parameters like turbidity, alkalinity and pH. He concluded that by providing affordable water filters to third world countries will greatly improve people's quality of living, and reduce the risk of any waterborne diseases therefore saving lives.

Rayner, 2009 identified the current Practices in manufacturing of ceramic pot filters for water treatment. Colloidal silver was applied for pathogen removal. Parameters were altered and its usage for different period was analyzed. Additional quality control, flow rate test and packaging were taken into consideration. Instead of cement, he used clay as the binding material and found that pressing, heating in furnace and drying are important procedures to be followed while making filters using clay and RHA.

2.2 Decontamination applications

RHA has good adsorptive properties and has been used for the removal of various dyes [*Rahman et al., 2005; Mane et al., 2007*], heavy metals [*Nakbanpote et al., 2000; Khalid et al., 2000; Kumar and Bandyopadhyay, 2006; Srivastava et al., 2007*], and other compounds like chlorinated hydrocarbons [*Imagawa et al., 2000*], palmytic acid [*Adam and Chua, 2004*], etc. High amount of ash indicates that RHA is basically inorganic in nature. Elemental analyses showed 7.424% carbon, 0.061% hydrogen and 0.846% nitrogen. The heating of rice husk at different temperatures produces RHA containing different contents of carbon and silicon dioxide. There are two possible mechanisms for the effect of pH on adsorption on any adsorbent: (a) electrostatic interaction between the protonated groups of carbon and acidic adsorbate, and (b) the chemical reaction between the adsorbate and the adsorbent [*Namasivayam and Kavitha, 2002*]. RHA particles contain a large number of functional groups –CO-, -OH, -Si-OH, -Si-H, -C-OH, etc. Adsorbate molecules may interact with these functional groups via pathways which are extremely complicated. Also, there may be weak electrostatic interaction between the electron-deficient sites on the surface of the RHA particles and adsorbate molecules. Aggregation of adsorbate molecules with the increase in contact time makes it almost impossible to diffuse deeper into the adsorbent structure at sites with highest energy. This aggregation diminishes the influence of contact time as the meso pores get filled up and start offering resistance to diffusion of aggregated dye molecules in the RHA. This is the reason why an insignificant enhancement in adsorption is effected in 7 days as compared to that in optimum time. An increase in temperature results in an increased mobility of the adsorbate and a decrease in the retarding forces acting on the diffusing adsorbate. This results in the enhancement in the sorptive capacity of the RHA.

The use of Rice Husk Ash in the removal of Methylene Blue (MB) from wastewater was investigated by *Chandrasekhar et al., 2006; Sharma et al., 2010*. Adsorption capacity of rice husk ash is due to the presence of both silica and carbon. The rice husk ash is a potential and cost effective adsorbent for the removal of methylene blue dye from aqueous systems. Adsorption of MB on RHA was reported to favorably influenced by an increase in the temperature of the operation. Similar study had been done for absorptive removal of Brilliant Green(BG) dye *Mane et al., 2006*, Indigo Carmine(IC) dye *Lakshmi et al., 2008* using Rice Husk Ash. Adsorption of IC and BG on RHA was favorably influenced by an increase in the temperature of the operation. *Sud et al., 2007* studied the use of agricultural waste in the removal of heavy metal from water. Agricultural waste material can be used as a potential adsorbent for sequestering heavy metal ions from aqueous solutions. It is highly efficient, low cost and renewable source of biomass can be exploited for heavy metal remediation.

Arsenic is becoming a main problem in drinking water these days. Its removal with the use of Rice Husk Ash has been investigated by *Saha et al., 2002; Laird, 2006; Mohan et al., 2007*. Rice Husk Ash can be used as an adsorbent for removal of Arsenic from water. The effect of contact times, pH and RHA dose on the removal efficiency of Arsenic by RHA has been accounted. Also *Saha et al. 2002* reported that 10 g/L of RHA dosage can remove Arsenic by 5-12%.*Feng et al., 2004* investigated the adsorption capacity of rice husk ash for the removal of lead and mercury in aqueous stream. The main finding of this research was that the finer the RHA particles used, the higher the pH of the solution, and the lower the concentration of potassium nitrate supporting electrolyte solution, the more lead and mercury are absorbed by rice husk ash**.**

Srivastava et al., 2007 has made an attempt to use rice husk ash (RHA), a waste obtained from the rice husk-fired furnaces, as an adsorbent in the removal of cadmium (Cd (II)) and zinc (Zn (II)) ions from binary systems. It is an effective adsorbent for the removal of Cd (II) and Zn (II) metal ions from aqueous solution. Higher percentage of metal ion removal was possible provided that the initial adsorbate concentration in the solution was low.

Ganvir et al., 2010 studied the removal of fluoride from drinking water using rice husk ash. RHA is obtained by burning rice/paddy husk which is an abundantly available and is an inexpensive raw agricultural material. The results depicted the excellent fluoride removal efficiency when Rice Husk Ash was coated with aluminum hydroxide.

Gandhi et al., 2012; Mondal et al., 2012 had done similar study on removal of fluoride from water and wastewater using low-cost adsorbents. The study was done for different parameters like dosage, concentration, time, temperature etc**.** *Imyim et al., 2010* studied the use of RHA in the removal of humic acid from water. He found that the RHA modified with aminopropylation reaction with 3-aminopropyltriethoxysilane is a suitable adsorbent for humic acid.

Wongjunda et al., 2010 studied the use of RHA in chromium removal. The modified RHA (MRHA) formed by treatment of RHA with NaOH has increased adsorption capacity for chromium removal. Microwave Incinerated Rice Husk Ash (MIRHA), produced from the rice husk is one of the low-cost materials that were used as adsorbent of heavy metal.

Johan et al., 2011 had made an attempt to use microwave incinerated rice husk ash for the adsorption of copper and found that it can be effectively used for the removal of copper through adsorption. BRHA has high adsorption capacity and low cost and may successfully be used as an effective sorbent for purification of crude oil or oil products spilled in water basins or bilge water, *Vlaev et al., 2011. Manique et al., 2011* had studied the purification of biodiesel from waste frying oil using Rice husk ash at different concentration. The high concentration of silica in its composition and the presence of meso and macro pores can explain its high capacity of adsorption.

Ghorbani et al., 2012 reported the results of study on the synthesis and performance of polypyrrole nanocomposite coated on rice husk ash in removing the heavy metals such as iron, zinc, copper and manganese from wastewater. The adsorbent materials adopted were found to be an efficient media for the removal of heavy metals in continuous mode using fixed bed column. *Sadon et al., 2012* had also studied the use of rice husk ash and modified rice husk ash by some chemical and physical treatment for the effective adsorption. Different parameters like contact time, temperature, pH were also studied. *Ahmaruzzaman et al., 2011; Singh et al., 2013* investigated study on the potential of adsorption of heavy metals from electroplating water using various agricultural adsorbents like rice husk ash, activated charcoal etc.

2.3 Other environment-friendly applications of RHA

The use of Rice Husk Ash in bitumen with other aggregates was reported in manufacture of building blocks ”Bitublocks” which can be used to construct a Bitublock wall *Forth et al., 2006; Thanaya, 2010.* This application resulted in less CO_2 emission also the amount of hazardous waste sent to the landfill gets reduced.The use of Rice Husk Ash in Concrete as an admixture enhances its properties *Saraswathy et al., 2006; Givi et al., 2010; Krishna, 2012.* RHA increases the resistance of concrete towards Chlorine and Sulphate and make it corrosion resistant. Also increases its workability, permeability and compressive strength. Similar work has been reported by *Khan et al., 2011* in which the use of Rice Husk Ash in concrete showed the reduction in environmental problem and cost reduction.

Muntohar, 2002 used various combination of RHA with Lime in soil and observed a decrease in soil swelling and improvement in strength and bearing capacity. Similar study was done by *Brooks, 2009; Rao et al., 2011* who used Rice Husk Ash and Rice Husk Ash in combination with Fly Ash respectively to upgrade expansive soil as a construction material. RHA can be used to stabilize the residual soil with or without mixing the cement. Its utilization is an alternative to reduce construction cost in the rural area of developing countries. *Sivapullaiah et al., 2004* explored the possibility of using Rice Husk Ash as a cushion. It was found that that RHA stabilized with 3-9% of lime or 10% cement and cured for about a week develops the properties required for an effective cushion material. *Basha et al., 2004; Alhassan, 2008; Hossain, 2011* had done the study on the stabilization of soil using Rice Husk Ash with cement and RHA with Lime and Gypsum respectively.

The production of silica from Rice Husk Ash was studied by *Mittal, 1997; Kalapathy et al., 1999. Mittal, 1997* also found that a By-product Sodium Silicate is formed during this process which can be used for making of good quality bricks. A green route to preparation of silica powders with rice husk ash and waste gas was investigated by *Dongmin et al., 2010*. Na_2CO_3 was used as the silica extraction reagent and waste gas was the precipitator. The synthetic procedure is inexpensive, environment-friendly and straightforward, which was suitable for large-scale production. Similar study was done by *Olawale et al., 2012* in which Rice Husk ash was characterized using atomic absorption spectrometer for optimal silica production. He reported that optimal silica was produced at characterization temperature of 7000°C. This will also reduce the environmental pollution caused by opening burning of rice husk. *Liu et al., 2012* worked on the production of Silica and activated carbon simultaneously from rice husk ash with Potassium carbonate, K_2CO_3.Potassium carbonate could be recycled. The entire synthetic procedure was simple, environmental-friendly and economical-effectively.

Dahlan et al., 2008 reported the work on the desulfurization of flue gas by using RHA/CaO sorbent with other additives. The SSC of RHA/CaO sorbent prepared with NaOH addition increases as the water vapor increases. *Lau et al., 2010* studied the use of RHA for the simultaneous removal of SO_2 and NO from flue gas using effective sorbent. He found that the sorbents synthesized from RHA and impregnated with CuO were found to be effective in removing SO_2 and NO simultaneously.

Ayswarya et al., 2012 studied the use of Rice Husk Ash as reinforcement for high density polyethylene. The use of RHA as a filler in HDPE reduces the pollution potential of RHA and modify the properties of HDPE by a cost effective and reliable method.

Lennox et al., 2008 studied the use of Rice Husk Ash for building of roads which prove to be environment-friendly. He mentioned that rice husk ash have been used to fire kilns making bricks for road construction and the ash could be also be used as a cement substitute for sub-base/surface strengthening or in bio-asphalt blends thus achieving a double benefit **.** *Pham, 2012* works on and takes into account the burning conditions affect to the rice husk ash applications in Geo engineering. He identified burning conditions to produce the rice husk ash and characterized the rice husk ash activity and estimated soil improvement ability of the rice husk.

2.4 Lacunae:

- Few scattered studies have been reported on the use of RHA for low cost water purification system.
- The affordability of RHA based water purification system has not been documented.
- The use of RHA in the removal of chlorides and sulfates has not been studied.
- The high amount of silica in RHA posing risk of water contamination has not been studied.
- The study of RHA based filter having different geometrical shapes has not been cited.

2.5 Objective:

- Preparation of low-cost RHA based filter for purification of water/ wastewater.
- Optimization of composition of RHA based filter to increase the treatment efficiency.
- Effect of operating parameter like contact time on the treatment efficiency.

CHAPTER-3

MATERIALS AND METHODOLOGY

This chapter deals with the materials used and the methods followed in the preparation of RHA based filters and the purification of various water/wastewater samples using these filters.

3.1 Materials:

Materials utilized for this study include

- **Ordinary Portland cement (OPC) -** OPC was collected from Rajpura, Punjab. It was used as a binding material for rice husk ash which provides strength to the matrix.
- **Rice Husk Ash** - RHA was procured from boiler house of a pulp and paper industry, it was used to make filter which act as an adsorbent.
- **Sand -** Sand was obtained locally from Zirakpur and it was used to provide strength to the mixture.
- **Water -** Fresh, colorless, odorless and tasteless potable water samples were collected from the different regions in Punjab, Haryana.
- **Wastewater** – Treated industrial effluent collected from industries in Punjab and Haryana.

3.2 Chemicals:

- Hydrochloric acid (HCl)
- Barium chloride solution-dissolve 100g $BaCl_2.2H_2O$ in one liter distilled water.
- Potassium chromate indicator or solution
- Standard silver nitrant.

All the chemicals were used as received. In all the experiments double distilled water was used.

3.3 Instruments

The following instruments were used in the measurement of various parameters during the treatment of water/wastewater samples with RHA based filter.

- **pH meter:** pH of the solution was monitored by using a digital desktop, pH meter (CP 901) from Century Instrument Company (Fig 3.1) and pH was adjusted with the help of 0.1 N NaOH and 0.1 N HCl. Instrument was calibrated with freshly prepared buffer solutions (of pH 4 and 9) from time to time throughout the study.

Figure 3.1 pH meter

- **Electrical conductivity meter:** Electrical conductivity of the samples was determined by using a Deluxe conductivity meter model 601 E (Eutech, India). The EC in (mS/cm) and TDS of water and wastewater samples were estimated (Fig 3.2).

Figure 3.2 Electrical conductivity meter

- **Turbidity meter:** Turbidity of the samples was measured by using Hatch Radio turbidometer as per Standard Methods (Fig 3.3) for the examination of water and wastewater.

Figure 3.3 Turbidity Meter

- **Filtration**: Water samples after treatment were filtered through Whatman's filter paper (No.42) and Ashless filter circles (4A grade).

- **TDS meter:** The TDS of the water samples was measured using TDS meter (TDS-3, HM digital) as shown in Fig 3.4.

Figure 3.4 TDS meter

3.4 Methodology

Following are the steps followed for the treatment of water/wastewater samples using RHA based filters.

3.4.1. Preparation of Filters

Different concentrations of RHA, cement and sand were taken to prepare column filters and ball filters. These concentrations were marked as C1, C2, C3 and C4.

- C1 - 100g of cement, 50g sand and 50g RHA
- C2 - 80g cement, 80g sand and 40g of RHA
- C3 - 100g cement, 75g sand and 25g RHA.
- C4 - 100g cement, 30g sand and 70g RHA.

3.4.1.1. Column filters

RHA and cement were taken in the quantities mentioned in Section 3.4.1 and thoroughly mixed. After that, the mixture was turned over number of times with the required amount of sand until an even color and consistency was observed. 100 ml water was added slowly and the mixture was further turned manually until a mixture of a sufficient workability was achieved. For column filter, the mixture was filled in the mould. Thereafter, the columns were dried for half an hour in an oven at a temperature of 97^{o}C and then air dried for 24 hours.

3.4.1.2. Ball filters

RHA and cement were taken in the quantities mentioned Section 3.4.1 and thoroughly mixed. After that, the mixture was turned over number of times with the required amount of sand until an even color and consistency was observed. 100 ml water was added slowly and the mixture was further turned manually until a mixture of a sufficient workability was achieved.

The balls of uniform size were prepared manually. Thereafter, the balls were dried for half an hour in an oven at a temperature of 97^{o}C and air dried for 24 hours.

3.4.1.3. Curing of Column and Balls

Curing process was identified as the most important part of the preparation of balls and columns using rice husk ash and cement because the strength gained by the column and ball depends upon the curing. Curing was commenced after 24 h of the drying by spraying normal water onto ball/column filter twice a day for 3 days.

3.4.2 Water Samples

Ground water samples were procured from following locations for treatment purpose -

1. Industrial area, Mandigobindgarh (Punjab)
2. Residential area, Ambala Cantt.
3. Residential area, Amloh.
4. Residential area, Jalandhar.
5. Residential area, Ludhiana.
6. Residential area, Muktsar.
7. Residential area, Patiala.

The treated industrial wastewater samples were procured from following locations for treatment purpose -

1. Industrial effluent-1(from an industry near Ludhiana)
2. Industrial effluent-2(from an industry near Manesar)
3. Industrial effluent-3(from an industry near Muktsar).

3.4.3 Use of column and ball filter for water purification

Quality of raw and treated water was measured by passing 300 ml water/wastewater samples through the column filters and ball filters of different concentrations mentioned in section 3.4.1. Retention time of 6 h was provided in the experiment and 50 ml aliquots were taken every hour for analysis. Treatment efficiency of samples at different duration was measured in terms of TSS and TDS. The estimation of chloride, sulfate and turbidity was done with the samples having high values of these parameters. Moreover, silica content of treated water was estimated in order to adjudge its chances of decontamination during treatment with RHA based filters. After all these experiments, the analysis on the repeatability and reuse of the ball and column filter was done for a sample for 10 cycles.

Chloride estimation was done using titrimetric method and estimation of sulfate was done using gravimetric method. Most of the parameters were measured following the APHA manual.

In **chloride estimation**, 50 ml of the sample was taken and pH was adjusted neutral (7-8) with H_2SO_4 or NaOH if it is not in this range (with the help of pH meter).After that, 2 drops of potassium chromate was added, while shaking it was titrated with N/35.45 (0,0141N) silver nitrate. The appearance of brick red colour was the end point of chloride ion.

Formula used:

$$\text{Chloride (mg/l)} = \frac{\text{ml sample} - \text{blank } AgNO_3 \times 1000}{\text{ml sample}}$$

In **sulfate estimation,** 50 ml of the sample was taken and pH was adjusted with HCl in case if it was found to be high, else 1ml of HCl was added in 50 ml sample then the sample was heated until it starts boiling and barium chloride was added slowly while stirring until the precipitate appears to be complete, 2ml of barium chloride was added in excess. Pre dry weight of Whatmann filter paper was taken, the sample was filtered slowly and the final weight of filter paper was measured when it was completely dry.

Formula used:

$$\text{Sulphate (mg/l)} = \frac{\text{mg}BaSO_4 \times 411.6}{\text{ml sample}}$$

The **turbidity** of the industrial sample before and after treatment was measured using turbidity meter.

The **silica estimation** was conducted by SAI labs, Thapar University, Patiala. APHA 22nd edition 4500 SiO_2 C, test method was followed for estimation.

CHAPTER-4

RESULTS AND DISCUSSIONS

The mixture of cement, sand and RHA was used to make the column filters and ball filters which were used for water/wastewater purification. The ratio of cement to RHA greater than one, in a mixture, was found to be suitable for the preparation of the filters as it provide the necessary strength to the filter media for water purification. The TSS of treated water was found to be higher when the ratio of cement to RHA was less than 1 which also reduces the strength of filter which in turn makes the filter brittle.

4.1 Characterization of water samples

Characterization of the collected ground water and wastewater samples was carried out by measuring its various physical characteristics such as TDS, TSS, chloride content, sulfate content and turbidity. The data given in Table 4.1 and 4.2 depicts that the all the parameters measured are higher for the wastewater sample collected from industrial location than the ground water samples collected from various locations. The ground water from Muktsar has quite high TDS and TSS as Muktsar is an industrial location where the chances of ground water pollution are high.

Table 4.1: Physical characteristic of raw ground water samples

Ground water sample	Parameters			
	TDS(ppm)	TSS(mg/l)	Chloride(mg/l)	Sulfate(mg/l)
Ambala Cantt	605	278	80	N.D
Amloh	429	308	80	N.D
Jalandhar	650	390	130	1.298186
Ludhiana	866	459	100	0.833902
Mandigobindgarh	628	540	120	N.D
Muktsar	1350	964	283	1.281722
Patiala	813	313	432	N.D

The industrial effluent-3 has higher amount of TDS, TSS and chloride than industrial effluent-1 and industrial effluent-2 as shown in Table 4.2.

Table 4.2: Physical characteristic of raw industrial wastewater samples

Wastewater sample	Parameters			
	TDS(ppm)	TSS(mg/l)	Chloride(mg/l)	Turbidity(NTU)
Industrial effluent-1	2050	800	1090	18
Industrial effluent-2	2570	970	1440	44
Industrial effluent-3	2960	1200	1940	60

4.2 Assessment of the comparative treatment efficacy of the ball and column filter

The ground water samples from two sites namely Industrial area, Mandigobindgarh and Residential area, Patiala were collected to assess the comparative treatment efficiency of the ball and column filter. The results as depicted by Fig. 4.1 show that the treatment efficiency in terms of TSS removal was 61, 79 and 88 % after 1, 2 and 3 h respectively, with ball filter and 50, 66 and 76% after 1, 2 and 3 h respectively, with column filter, both having composition 100 g cement, 50 g sand and 50 g RHA for the treatment of Industrial area, Mandigobindgarh.

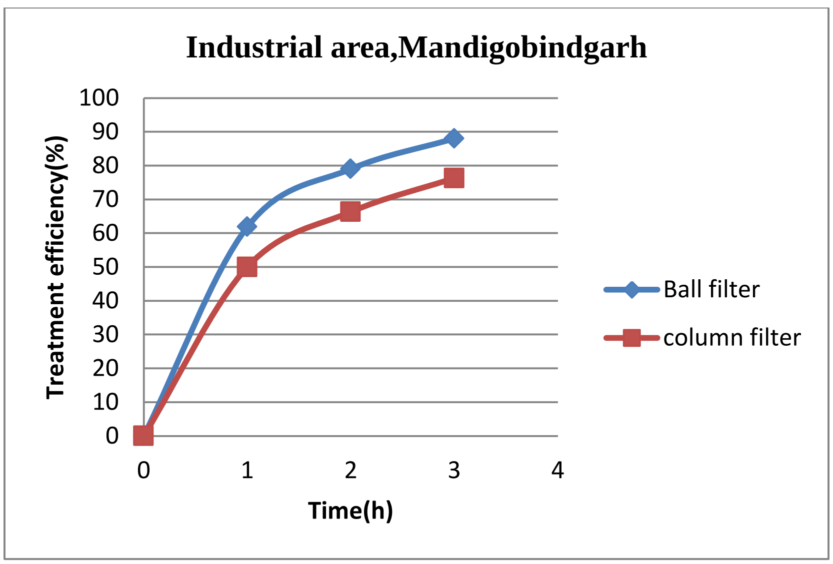

Figure 4.1: Comparison of the treatment efficiency using column and ball filter for industrial area.

The results as depicted by Fig. 4.2 show that the treatment efficiency in terms of TSS removal was 63, 81 and 88 % after 1, 2 and 3 h respectively, with ball filter and 48, 64 and 69% after 1, 2 and 3 h respectively, with column filter, both having composition 100 g cement, 50 g sand and 50 g RHA for the treatment of Residential area, Patiala.

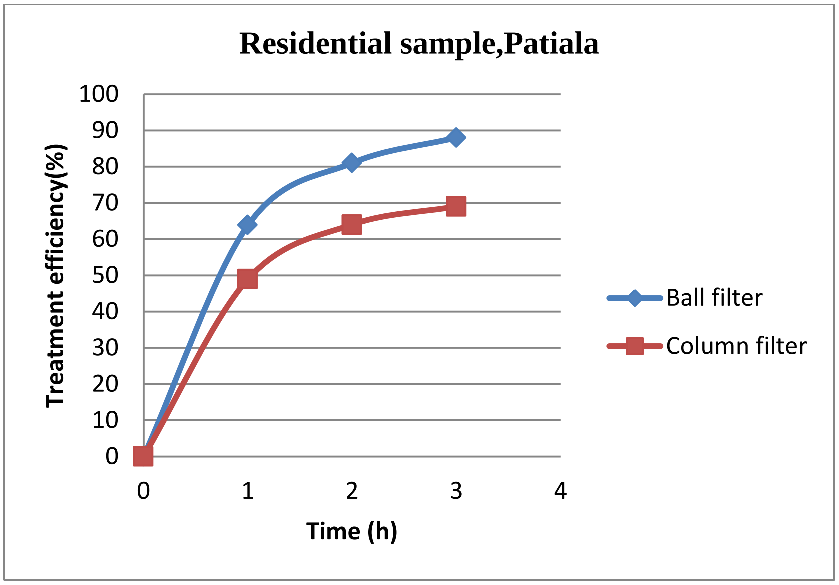

Figure 4.2: Comparison of the treatment efficiency using column and ball filter for residential area.

The treatment efficiency was found to be a function of time because the efficiency depends upon the adsorption coefficient which varies with the passage of the time. It is evident from the results that the rate of adsorption is more in the first 1 h in the ball and column filters because of the availability of more no. of active sites for adsorption and then the increase in rate of adsorption became less in the remaining time period due to the decrease in the active sites for adsorption.

4.3 Assessment of the comparative TDS removal of the ball and column filter

The comparative TDS removal of the ball and column filter was analyzed for water samples mentioned above in section 4.2. As shown in Figure 4.3, for Mandigobindgarh, the TDS removal was 20, 27and 30 % after 1, 2 and 3 h respectively, with ball filter and 15, 22 and 24% after 1, 2 and 3 h respectively, with column filter, both having composition 100 g cement, 50 g sand and 50 g RHA.

The results as depicted by Fig. 4.4 show that the TDS removal was 21, 28 and 31 % after 1, 2 and 3 h respectively, with ball filter and 16, 21 and 23% after 1, 2 and 3 h respectively, with column filter for the treatment of ground water sample from residential area, Patiala. It was observed in the results that the initial TDS of Patiala sample is higher than Mandigobindgarh, so, TDS removal is more in former as more adsorbate is available for adsorption. It was observed from results in section 4.2 and 4.3 that the efficiency of ball filter is better in removing the TDS and TSS from water/wastewater samples than column filter so further experiments were performed using the ball filters.

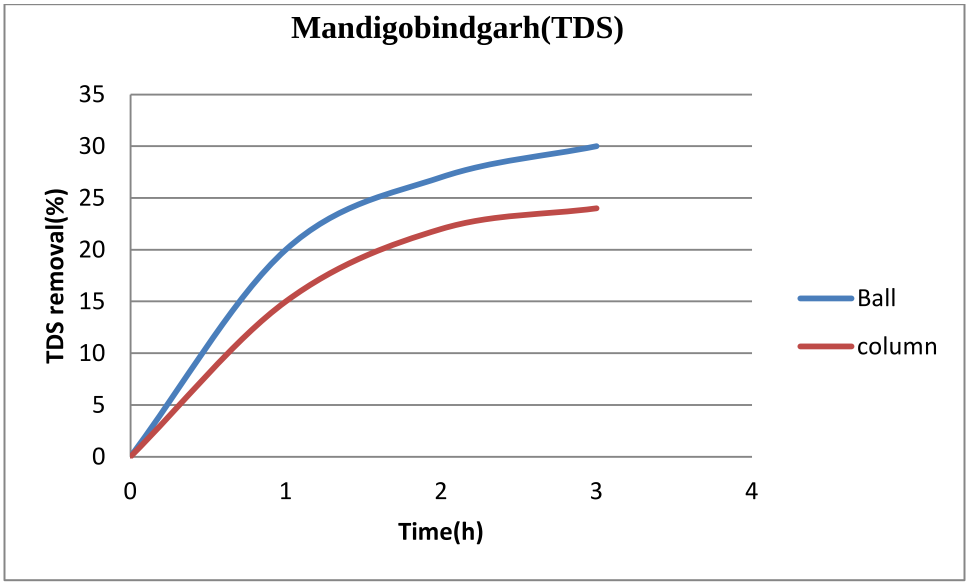

Figure 4.3: Comparison of the TDS removal using column and ball filter for industrial area.

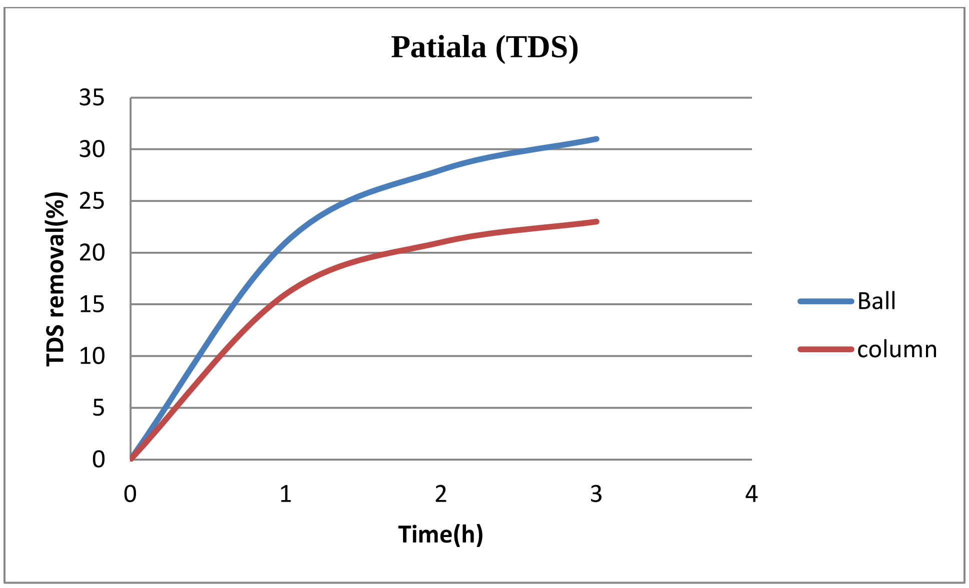

Figure 4.4: Comparison of the TDS removal using column and ball filter for residential area.

4.4 Effect of different composition of RHA in ball filters

For comparing the treatment efficiency of different composition of ball filters as mentioned in Section 3.4.1, the ground water sample were taken from different locations like Ambala cantt, Amloh, Muktsar, Patiala, Ludhiana in order to adjudge the composition that is most efficient in removing TDS.

The treatment efficiency in terms of TDS was calculated after treatment with ball filter for 6 h. As given in Figure 4.5, the treatment efficiency for different samples came out to be in the range of 31-43% for C1 ball filter, 25-38% for C2 ball filter and 21-28% for C3 ball filter .It shows that C1 (100g cement, 50 g sand and 50g RHA) ball filter is efficient in TDS removal as compared to ball filters of other compositions. The low amount of RHA results in lower no. of active sites available for adsorption. So the treatment efficiency decreases. The high concentration of silica in RHA and the presence of meso and macro pores are responsible for high capacity of adsorption in case of C1 ball filter.

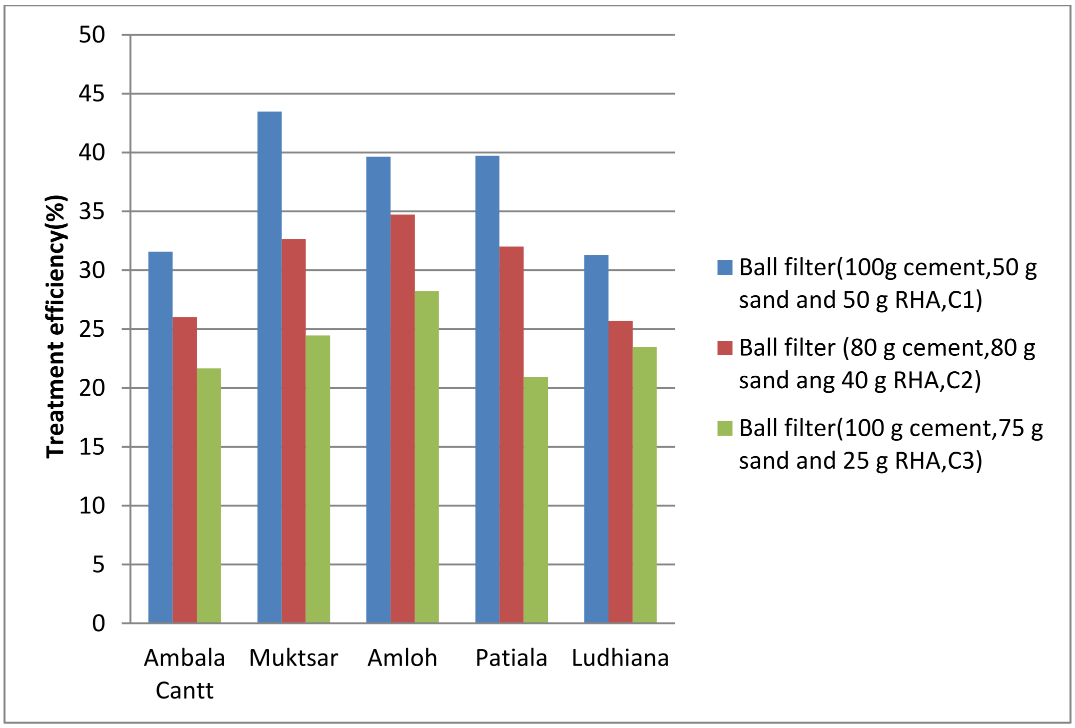

Figure 4.5: Effect of different concentration on treatment efficiency (TDS) for ball filters for different samples

Further increasing the RHA concentration as in the composition of 100g cement, 30g sand and 70g RHA for ball filters was not found to be suitable because of less strength and these balls lose their shape as soon as they were dropped in water for clarification. This in turn increases the TSS of water sample whereas the ball filters having composition ratio, cement to RHA greater than 1 were effective for treatment of water/wastewater. So, further experiments were performed using the ball filter with composition 100g cement, 50 g sand and 50g RHA.

4.5 Effect of contact time

In order to establish the optimum contact time required for obtaining desired treatment efficiency in terms of TDS removal, experiments were conducted with C1 composition of ball filter for a period of 6 h and TDS was measured at an interval of 1 h. The ground water samples collected from Ambala Cantt, Muktsar, Amloh, Patiala, Ludhiana and the wastewater samples collected from industries were subjected to treatment. The increased contact time provided in treatment increase the rate of adsorption but at the expense of increased recurring cost.

The results in Fig 4.6 depict that the treatment efficiency of ground water sample of Ambala Cantt came out to be 14%, 21%, 25%, 29%, 30% and 31 % after 1, 2, 3, 4, 5 and 6 h respectively. It was observed that the increase in adsorption is considerable in first 4 h but after that the increase in adsorption is less significant and becomes almost constant after 6 h of treatment. Similar trend in results were observed for the other ground water samples in which the rate in increase of adsorption was less after 4 h.

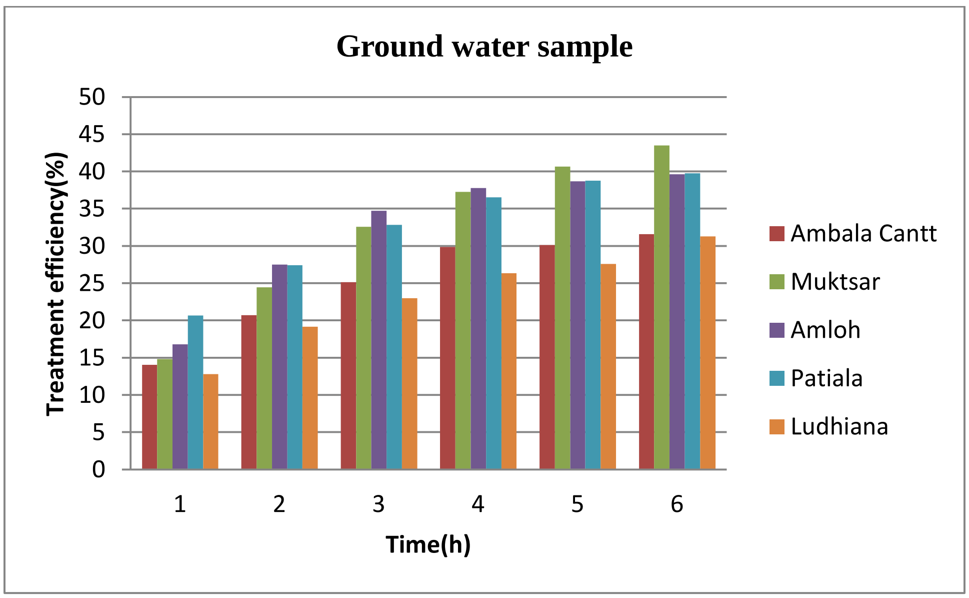

Figure 4.6: Effect of contact time on treatment efficiency (TDS) for ground water samples.

The graph in Fig 4.7 shows the treatment efficiency of the different wastewater samples with C1 ball filter at different retention time up to 6 h. For industrial effluent-1, the treatment efficiency in terms of TDS removal increases from 10 to 28% till 4 h but after that the rate of increase in adsorption decreases and the treatment efficiency came out to be 31% in another 2 h. Similar trend in results were also observed for industrial effluent-2 and industrial effluent-3. The probable reason for this behavior is that initially the ball filter has more active sites for adsorption but as the time increases these sites get filled up and it creates a hindrance for the adsorbate to get into the active site so the adsorption decreases. So, the contact time of 4 h was chosen to be the optimum time for linking between adsorbate and adsorbent for the removal of TDS from water/wastewater samples. Further, the increase in contact time beyond 4 h will increase the cost of treatment without much reduction in TDS.

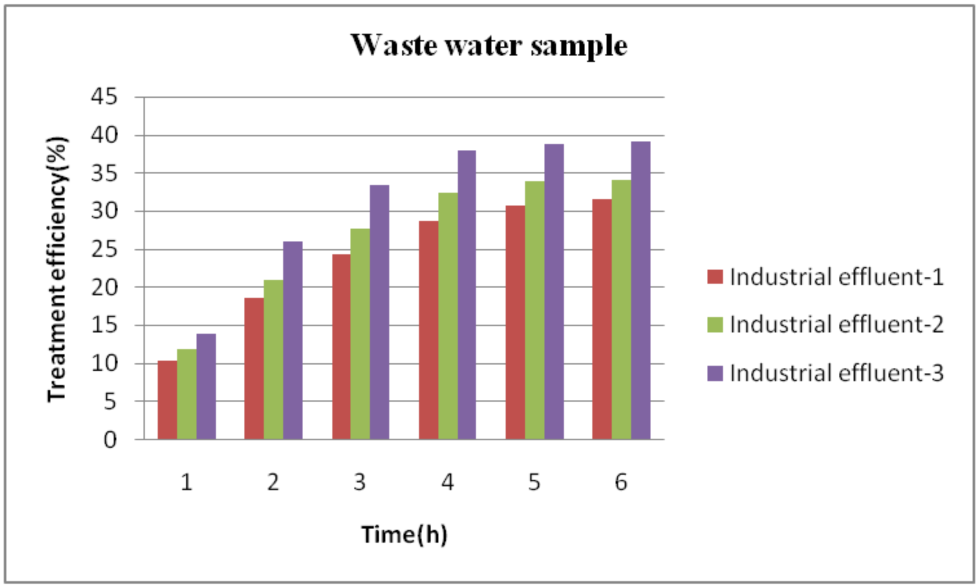

Figure 4.7: Effect of contact time on treatment efficiency (TDS) for wastewater samples.

4.6 Estimation of chlorides

The estimation of chloride was done using the RHA based ball filter having composition 100g cement,50g sand and 50g RHA for ground water samples from Muktsar and Patiala as the initial chloride content in these water samples was greater than the permissible limit i.e. 250mg/l as mentioned in Table 4.1.The graph in Fig 4.8 shows the reduction in chloride from 283 mg/l to 189 mg/l i.e. 33% reduction after 6 h of retention time for the ground water sample from Muktsar where as the reduction in chloride was 36% after 6 h for the ground water sample from Patiala.

The initial chloride content of industrial effluent-1 and industrial effluent-3 was 1090 and 1940 mg/l respectively (Table 4.1). The results in Figure 4.9 show a considerable reduction in chloride content of industrial effluent-1 from 1090 mg/l to 611 mg/l (44%) after 6 h whereas the reduction in industrial effluent-3 was 47% i.e. from 1940 mg/l to 1028 mg/l. As the amount of chloride present initially is higher in case of wastewater samples than ground water sample so more chloride is available for adsorption on the surface of adsorbent (RHA based ball filter) which in turn increases its removal efficiency of chloride in case of industrial effluents.

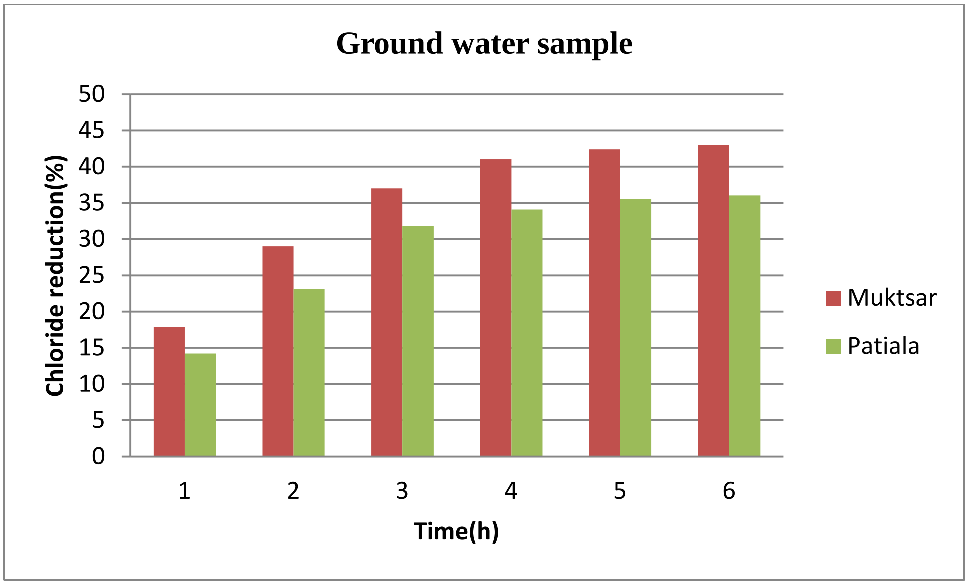

Figure 4.8: The percentage chloride reduction for ground water samples using ball filter (100g cement, 50g sand and 50 g RHA) for 6h.

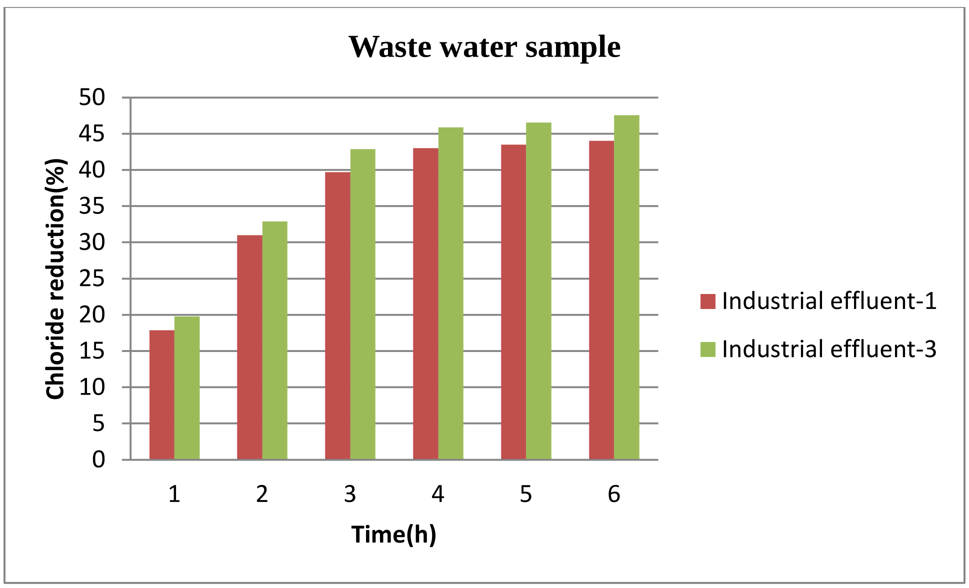

Figure 4.9: The percentage chloride reduction for wastewater samples using ball filter (100g cement, 50g sand and 50 g RHA) for 6h.

4.7 Sulfate estimation

The sulfate estimation was done for treated ground water sample from Jalandhar, Ludhiana and Muktsar; other samples were not analyzed as the sulfate content was not detectable in untreated ground water sample as shown in Table 4.1. Although the initial sulfate concentration was not so high in these samples but after passing through the RHA based ball filter, a considerable reduction was noticed after 6h of treatment as shown in the Table 4.3.

Table 4.3: Sulfate concentration in samples initially and after 6h of treatment

Sample	Sulfate concentration(mg/l)	
	Initial	Final
Jalandhar	1.298186	1.0518
Muktsar	1.281722	0.993602
Ludhiana	0.833902	0.57871

4.8 Turbidity estimation

The turbidity of ground water samples collected came out to be zero whereas the industrial samples collected were turbid with initial values as mentioned in Table 4.2. The decrease in turbidity after treatment was measured using turbidity meter for the industrial samples with C1 ball filters after 6 h. The results in Table 4.4 show that the reduction in turbidity was around 40%, 60% and 55% for industrial effluent-1, industrial effluent-2 and industrial effluent-3 respectively. As the suspended solids present in the water sample decreases the turbidity of water automatically decreases.

Table 4.4: Turbidity level in wastewater samples initially and after 6 h of treatment

Sample	Turbidity(NTU)	
	Initial	Final
Industrial effluent-1	18	10.8
Industrial effluent-2	44	17.6
Industrial effluent-3	60	27

4.9 Silica estimation

As silica is one of the major component of rice husk ash used in the manufacture of the ball filter so there was a threat of increase of silica content in the treated water sample which could be harmful if present in excess in the potable water. So, an experiment to measure the amount of silica was conducted by SAI labs, Thapar University, Patiala. The results from Table 4.5 show that the amount of silica is consistent in the water sample even after 6 h of treatment with ball filters. The amount of silica in ground water sample from Muktsar was found to be 13.7 mg/l before treatment and the silica concentration was found to be 13.2 mg/l after 3h of treatment with RHA based ball filters. Similar test was done for ground water sample from Patiala, the concentration of silica in the sample before and after 6h of treatment process was 11.1 mg/l and 11.3 mg/l respectively. So it can be concluded that there is no increase in silica content during the treatment of ground water samples with RHA based ball filters.

Table 4.5 Silica concentrations in samples initially and after treatment with RHA ball filter (100g, 50g sand and 50g RHA)

Sample	Silica concentration(mg/l)	
	Initial	**Final**
Muktsar	13.7	13.2
Patiala	11.1	11.3

4.10 Filter reuse and repeatability

The experiment for repeatability of ball filter in the treatment of ground water was conducted of Muktsar with the C1 concentration of ball and column filter. This particular sample was chosen as its treatment efficiency in terms of TDS removal was found to be good with ball filters as mentioned in Section 4.3.When ball and column filters were used repeatedly, it was observed that the ball filters can be used more number of times whereas the efficiency of column filter started decreasing after few treatment cycles as shown in Fig 4.10. The efficiency of ball filters reduced from 44% to 9.99 % after 10 cycles of treatment whereas the column filters were inefficient after 4 cycles of treatment (5%). The reason for this could be the high surface area present in case of ball filters as compared to the column filter. As a result, after few initial treatments, column filter became inefficient in reducing the TDS from the water samples as compared to the ball filter.

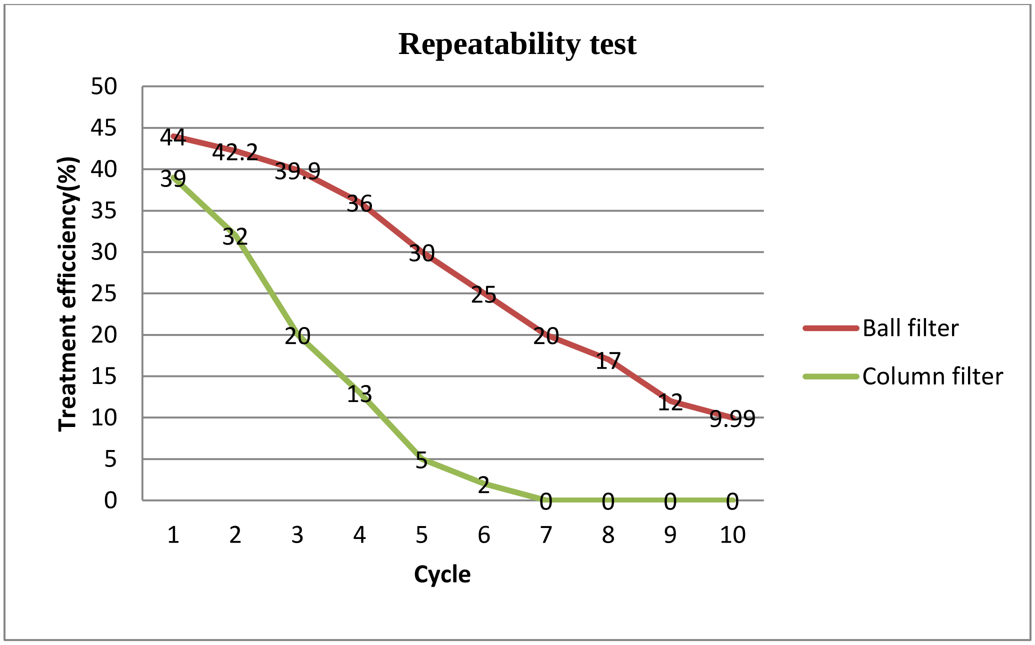

Figure 4.10: The effect of repeatability of treatment on treatment efficiency.

CHAPTER-5

CONCLUSION

The presence of safe and reliable water is an essential prerequisite for a stable community. Water used for drinking becomes unpalatable when the TDS level is above 500 mg/l, but lack of any better source enables people consuming such water to get used to its taste. Practically, all industrial and some commercial uses, the purity levels required are very much higher and in most cases demand water with virtually no residual dissolved solids at all. The potential of use of RHA as an adsorbent for the reduction of TDS in water and wastewater samples has been explored. The RHA based ball and column filter were prepared and subjected to water/wastewater purification. The results depict that the ball filter showed better treatment efficiency than the column filter in terms of TSS and TDS removal. The high concentration of silica in its composition and the presence of meso and macro pores can explain its high capacity of adsorption. The optimization of composition of RHA based ball filter was done and it was found that the ratio of cement to RHA should be greater than one for RHA ball filter otherwise the ball lose their strength when used for treatment and hence, results in increase in TSS. The composition of 100g cement, 50 g sand and 50 g RHA was found to be optimal for the TDS removal from water/wastewater. The retention time of 4 h was chosen for the treatment of water/wastewater using the ball filter with above mentioned composition because after 4 h of retention time, the results showed insignificant increase of adsorption that varies from 29 to 30% for ground water sample from Ambala Cantt. Similar pattern in results was observed for other ground and wastewater samples also. A considerable reduction was observed in chloride concentration from 33 to 36% for water i.e. and 44 to 47% for wastewater samples. In case of wastewater, the final chloride content after treatment was not within permissible limit i.e. 250 mg/l so this filtration system can be used as a preliminary treatment step before applying other conventional treatment technologies. This will reduce the load on the secondary techniques as the TDS and Chloride would have been already removed by RHA based filters used for preliminary treatment. Even though the sulfate concentration was not high in ground water sample but a small reduction was observed in the content of sulfate also. For the ground water sample from Jalandhar the reduction in sulfate was 1.05 mg/l from 1.22 mg/l. The presence of high turbidity was observed in the industrial sample from various locations and up to 60% reduction in turbidity was observed in industrial effluent-3. In order to establish the silica content in treated water samples, the silica content was estimated and it was observed that the amount of silica was consistent in the treated and untreated ground water samples. The amount of silica present in ground water sample from Patiala was 11.1 mg/l before treatment and 11.3 mg/l after treatment for 6 h with ball filters having composition 100 g cement, 50 g sand and 50 g RHA. The reusability and repeatability of ball and column filter was determined by treating water sample for 10 cycles of treatment and it was found that the ball filter was more efficient in removing TDS up to 10 cycles, although the efficiency got reduced from 44 to 9% after 10 cycles of treatment whereas the column filter became less efficient after 4 cycles. The use of rice husk ash in making of the filters for water purification will provide two fold advantage to the environmental management. First, the large volume of rice husk waste could be partly reduced, converted to useful, value added adsorbent. Secondly, the development of the low-cost adsorbent may overcome the water and wastewaters pollution problem at an affordable cost. The utilization of rice husk would solve both a disposal problem and also access to less-expensive filter medium in the wastewater treatment and these types of filters may be used by rural people to treat drinking water at low cost .

Future prospects

The used RHA based balls after the treatment, can be further utilized for construction purpose i.e. in the construction of bitublock wall, in concrete making or it can be used in road surfacing in addition with the bitumen. These ball filters can be coated with lime for the removal of fluoride from water. Additional modification of RHA can be done for removal of other constituents and heavy metals from wastewater.

CHAPTER-6

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- Ranu Pachauri and Amit Dhir, "Use of rice husk ash in making of filters for water purification" A paper presented at GTSEM-13 held at Doon University, Dehradun, 22^{th} & 23^{th} March 2013.