Design, Installation and performance evaluation of low budget drinking water filter for rural areas of Haryana

A thesis submitted to the

University of Petroleum and Energy Studies

For the award of

Doctor of Philosophy

in

Health Safety & Environmental Engineering

BY

Prasenjit Mondal

JANUARY 2021

SUPERVISOR (s)

Dr. B. P. Yadav

Dr. N. A. Siddiqui

UPES
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HSE & Civil Engineering Department

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Supervisor

Dr. B. P. Yadav,
Associate Professor,
HSE & Civil Engineering Department,
University of Petroleum &Energy Studies, Dehradun

Co-supervisor

Dr. N. A. Siddiqui,
Professor,
HSE & Civil Engineering Department,
University of Petroleum &Energy Studies, Dehradun

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School of Engineering
University of Petroleum and Energy Studies
Dehradun-248007; Uttarakhand

Declaration

I declare that the thesis entitled **"Design, Installation and performance evaluation of low budget drinking water filter for rural areas of Haryana"** has been prepared by me under the supervision of Dr. B. P. Yadav, Associate Professor of Department of HSE and Civil Engineering, University of Petroleum and Energy Studies, Dehradun and Dr. Nihal Anwar Siddiqui, Professor of Department of HSE and Civil Engineering, University of Petroleum and Energy Studies, Dehradun. No part of this thesis has formed the basis for the award of any degree or fellowship previously. This written submission represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission.

Prasenjit Mondal
(SAP ID - 500042934)
Date: 07 Apr. 2021
Place: Dehradun

Certificate

I certify that Prasenjit Mondal has prepared this thesis entitled **"Design, Installation and performance evaluation of low budget drinking water filter for rural areas of Haryana"** for the award of PhD degree of Department of HSE and Civil Engineering, University of Petroleum and Energy Studies, Dehradun. He has carried out the work at Department of HSE and Civil Engineering, University of Petroleum and Energy Studies, Dehradun

Supervisor
Dr. B. P. Yadav
Associate Professor
Department of HSE and Civil Engineering
University of Petroleum and Energy Studies, Dehradun
Date: 07/04/2021
Place: Dehradun

Energy Acres: Bidholi Via Prem Nagar, Dehradun - 248 007 (Uttarakhand), India T: +91 135 2770137, 2776053/54/91, 2776201,9997799474 F: +91 135 2776090/95
Knowledge Acres: Kandoli Via Prem Nagar, Dehradun - 248 007 (Uttarakhand), India T: +91 8171979021/2/3, 7060111775

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Supervisor
Dr. N. A. Siddiqui
Professor
Department of HSE and Civil Engineering
University of Petroleum and Energy Studies, Dehradun
Date: 07/04/2021
Place: Dehradun

Thesis Completion Certificate

I certify that the thesis entitled "Design, Installation and performance evaluation of low budget drinking water filter for rural areas of Haryana" by Prasenjit Mondal in partial completion of requirement for the award of degree of Doctor of Philosophy (in Engineering) is an original work carried out by him under our joint supervision and guidance.

This is certify that the work has not been submitted anywhere else for the award of any other diploma or degree of this or other university.

Supervisor I
Dr. Bikarama Prasad Yadav
Associate Professor
Department of Health Safety and Environment
University of Petroleum &Energy Studies, Dehradun

Supervisor II
Dr. Nihal Anwar Siddiqui
Professor
Department of Health Safety and Environment
University of Petroleum &Energy, Dehradun

Abstract

With increasing demand of drinking water quality, a group of scientists regularly trying to incorporate unique and cost effective strategies for water treatment. As population graph of India bents towards up very stiff, scares the viability of quality drinking water in near future. Various research articles, reports, news etc. are continuously alarming us to think about alternate treatment options.

The thesis consists of total five chapters, in which Introduction, Literature review, Research methodology, Results & discussions and conclusions are elaborated with consideration of unique water treatment strategy which can be use especially for rural areas.

Initially, water quality of various locations of Haryana were studied and analyzed through literature and followed by laboratory test over same parameters. In both of the cases it was found that some of the heavy metals and ions are major problem in ground water of Haryana. The presence of industries, agricultural practices and other natural events may leads the ground water through those pollutants. A total of 8 location in random 8 districts of Haryana were considered and analyzed. Out of all the locations, Gurgaon water quality were found to be worst. Values of Fluoride (mg/L), Cadmium (µg/L), and Lead (µg/L) were found to be 1.75, 5.25 and 14.65 respectively. The standard values of these parameters are 1 mg/L, 3 µg/L and 10 µg/L respectively.

Health related issues due to bad quality of drinking water were studied and analyzed through research papers and followed by actual field survey. Main health related problem were found to be Kidney Damage, Damage to the brain, nervous system issue, red blood cells related issue, Muscle disorders, Thyroid disease, Arthritis, Dementia, Bone fractures, Bone cancer, Genetic damage, Increased tumor and cancer rate, Damaged sperm and increased infertility, Cardiovascular disease, Growth retardation, and Reproductive failure. A total of 65 family were surveyed which includes total of 289 family members of various age groups and collected data were analyzed. From the analyzed data it was found that mostly Kidney related and muscle related disease are being faced by local people.

Water sample of Gurgaon were considered as inlet water to treat using various bio adsorbents to optimize the doses and finally utilize the same in designed water treatment unit. Orange peels, sugarcane husk and rice husk of size range 500 µm, 750 µm and 1000 µm were used with dose range from 1 g/L to 10 g/L. Best bio adsorbent for removal of Cd, Pb and F- were found Orange peels of size 500 µm, rice husk of size 500 µm and sugarcane husk of size 500 µm respectively. Best combination of adsorbents can bring down the level of Cd, Pb and F- as 2.47 µg/L, 7.35 µg/L and 0.34 mg/L respectively. Optimum dose for all three cases were found to be 3 g/L.

Three adsorbent packed column namely orange peel column, rice husk column and sugarcane husk column are connected in series. Outlet of one column ends as inlet of next column to enhance sequential treatment and removal of unwanted substances. Best and optimized size of adsorbents at all the columns are 500 µm. various adsorbents are having ability to remove various heavy metals (Pb and Cd) and ions (Fluoride). Specifications of the filter like length (36cm), diameter (12 cm) and bottom mechanism of every column has designed in such a way, it can enhance best adsorption time to remove substances and water can flow through gravitational force. The main function of bottom mechanism is to restrict water to carry adsorbent materials. At the end one 36 cm long settling tank has been provided to enhance the settlement of remaining adsorbent from treated drinking water.

Cost for various components like PVC 5 inch diameter pipe, PVC 5 inch diameter cap, PVC 4 inch diameter pipe, PVC 3 inch diameter pipe, PVC solvent and PVC 2 cm diameter are INR 128.25, 148, 12.1, 9.7, 25 and 33 respectively. A total cost for raw materials were calculated and rounded as INR 360/. Other costs for this study were includes Cost of fabrication, Cost of Adsorbent, Cost for electricity and Cost of maintenance and calculated values were INR 250, 175, 0 and 350 respectively.

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I express my sincere acknowledgement to my PhD supervisors Dr. B. P. Yadav and Dr. N. A. Siddiqui for their continuous support and motivation throughout the PhD duration. Their guidance helped me in all the time of research and writing of this thesis.

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Prasenjit Mondal

Date:

Table of Contents

List of Figures

List of Tables

List of Abbreviations

WHO	World Health Organization
RO	Reverse Osmosis
IS	Indian Standard
APHA	American Public Health Association
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
i.e.	That is
INR	Indian Rupees
USD	United State Dollar
ppm	Parts per million
NTU	Nephelometric Turbidity Units
TDS	Total Dissolved Solid
TS	Total Solids
UV	Ultraviolet
AAS	Atomic Absorption Spectrophotometer
UN	United Nation
UNESCO	United Nations Educational, Scientific and Cultural Organization

Chapter 1
Introduction

1.1. Title of thesis

Design, Installation and performance evaluation of low budget drinking water filter for rural areas of Haryana

1.2. Problem statement

- Water crisis to intensify across India by 2050, warns UN report (2018)
- High risk of poor water quality in India's river basins by 2050: UNESCO report (Mar 20, 2018 – Hindustan Times)
- Surface and groundwater pollution are pushing India towards a water crisis (source: swachhindia.ndtv.com)
- Currently available drinking water filters are not cost effective for rural areas as well as these techniques requires chemicals and other costly raw materials.
- In RO technique water use rate is 1:5. (source: Yanık, et al. (2008))
- Regular maintenance and replacement of packed materials requires for recent available filters.
- This topic will deal with design, development of low budget as well as low maintenance filter.

1.3. Background

The main constituent of our body is water (70%) and percentage of water present in various essential part of human body (brain - 85%, liver - 90%, blood - 83% bones 35% etc.) shows the importance of drinking water consumption in daily life (Lakhote et al., 2016). According to the WHO (World Health Organization), over 1.34 billion people are lacking to access safe drinking water and this has led to extensive contamination of ground/surface water. Contagious diseases associated with drinking water accounts up to 3.3 million lives every year and approximately 6.2% of all deaths worldwide. The load of diseases from inadequate water, sanitation, and hygiene totals 1.81 million deaths and the loss of greater than 76 million healthy lives (Tzoulas et al., 2007). It is well accepted that investments in safe drinking water and improved sanitation show a close correspondence with advancement in human health and economic productivity. Each person needs 25 to 50 liters of water free of harmful chemical and microbial contaminants each day for drinking, cooking and maintain hygiene (Tzoulas et al., 2007). Tap water is the major supply of our drinking water but it is actually not impregnable to consume it regularly as it contains high level of chlorine, leads, fine microscopic which causes cloudiness, bad taste and smell, and also bacteria. The used water is being treated to be reused which means large amount of chlorine is used in order to cleanse it. Tap water that is devour every day is not safe as it contains high level of chlorine, leads, fine microscopic which causes haziness, bad taste and smell, and also micro bacteria. However, this matter can be unexpectedly by first, filter the water and after that boil it. Different types of portable water filters available, with varying degrees of effectiveness, can be used together with physical and chemical purification. Portable water filters are usually small, portable and light (1.0-1.5 kg) and usually filter water by working a mechanical hand pumps, although some use a siphon drip system to force water through while others are built right into water bottles. A water filter is a setup which removes impurities from water by means of a fine physical barrier, a chemical process and biological process. Filtration controls entirely on particle or droplet size (and, to some extent, shape), such that particles below a certain size will pass through the hurdle, while larger particles are retained on or in the barrier for later removal (El-Harbawi, 2010).There are a number of tap water filtration systems available in the market, but not all of them are of good quality.

The technology is highly improved and the water produced by these filters is much safer and cleaner than ever before. However, recently it is hard to find a portable water filter where consumers can carry it anywhere and used it for more than one purpose. Hence, we have come out with a solution to design a portable water filter with extra feature, which is the heating element to boil the water. In terms of scientific point of view boiling would be able to kill all the germs and microorganism in the tap water. There are a few aspects that needed to be considered in the design process which are economical, convenient and user friendly in rural areas.

1.4. Research Gap

- Numbers of water filters are innovated by researchers and are available in market, but feasibility of those filter for rural areas are not acceptable in terms of installation cost, maintenance and power requirement (Hegazi, H. A. - 2013).

- Replacement of various sub-part of water filter like RO unit and other filter media is also a hectic work each year rather than we can use organic filler substances. (Mohamad E. L. Harbau - 2010).

- Organic filler substances are widely using for the research work but there is no implementation till date. (Hegazi 2013).

- There is a huge gap in the research to eliminate heavy metals from drinking water. (Al-Qahtani 2016).

1.5. Motivation/need for research

The rural population of India comprises more than 700 million people residing in about 1.42 million habitations spread over 15 diverse ecological regions. It is true that providing drinking water to such a large population is an enormous challenge. Our country is also characterized by non-uniformity in level of awareness, socio-economic development, education, poverty, practices and rituals which add to the complexity of providing water. The health burden of poor water quality is enormous. It is estimated that around 37.7 million Indians are affected by waterborne diseases annually, 1.5 million children are estimated to die of diarrhea alone and 73 million working days are lost due to waterborne disease each year. The resulting economic burden is estimated at $600 million a year. The problems of chemical contamination are also prevalent in India with 195813 habitations in the country are affected by poor water quality.

1.6. Objectives

1. To identify and analyze issues related with potable water in rural areas of Haryana: (check the quality of water and relevant health issues)

2. To identify the effective organic absorbent for removal of different pollutants of ground water of specific areas of state Haryana for removal of contaminants of interest.
3. To design, install and evaluate the performance of water filter: (innovative steps of filtration, detailed calculation of all the specifications, capacity, filtrated water quality, comparison with initial values and standards)
4. To analyze water wastage ratio, cost and other inputs (like: power requirement, raw material and time)

Chapter 2
Literature Review

2.1. Prescribed range of water quality parameter

To get clear idea about the characteristics of groundwater at various part of state "Haryana" a wide range of literature has been surveyed and the subsequent data were mentioned in various data tables. While we consider the quality of water specially ground water, standard or prescribed range given by various standards agencies plays an important role. Thus drinking water standard IS10500:2012 were studies thoroughly and the relevant data those are useful for the current study mentioned. Acceptable limit of heavy metals in drinking water and PEL value as per IS10500:2012 has been mentioned in the table 2.1.

Table 2.1. Standard value of heavy metals as per IS10500:2012

S No	Element	Acceptable Limit µg/L (BIS 10500:2012)	PEL µg/L (BIS 10500:2012)
01	Arsenic	10	50
02	Cadmium	3	No relaxation
03	Chromium	50	No relaxation
04	Copper	50	1500
05	Iron	300	No relaxation
06	Lead	10	No relaxation
07	Mercury	1	No relaxation
08	Nickel	20	No relaxation

Apart from heavy metals the standard value of other quality parameter of ground water has been studied. Acceptable limit and PEL value as per IS10500:2012 has been mentioned in the table 2.2. In the data table for some toxic and hazardous parameter, there is no relaxation in the value of PEL were found.

Table 2.2. General Parameters Concerning Substances Undesirable in Excessive Amounts:

S. No.	Element	Acceptable Limit mg/L (BIS 10500:2012)	PEL mg/L (BIS 10500:2012)
01	Aluminum	0.03	0.2
02	Ammonia	0.5	No relaxation
03	Barium	0.7	No relaxation
04	Boron	0.5	1
05	Chloride	250	1000
06	Copper	0.05	1.5
07	Calcium	75	200
08	Fluoride	1.0	1.5
09	Iron	0.3	No relaxation
10	Magnesium	30	100
11	Manganese	0.1	0.3
12	Nitrate	45	No relaxation
13	Silver	0.1	No relaxation
14	Sulphate	200	400
15	Sulphide	0.05	No relaxation
16	Total Hardness	200	600
17	Zinc	5	15

2.2. Distribution of heavy metals in various states of India

As the present study deals with the treatment of drinking water with consideration of groundwater of state Haryana. A survey based on literature plays a vital role to find out distribution of heavy metals in various states of India and the same has been represented in Fig 2.1. The study says a wide range of heavy metals present ground water in various concentration based on their geographical location, agricultural practices, industrial functionalities and domestic disposal practices. The heavy metals i.e. lead, mercury, arsenic, uranium, cadmium, chromium etc. generally present in various places. If we consider heavy metals present in Haryana, mainly three i.e. Mercury, lead and cadmium were present. To make a clarification the characteristics of the same has been studied in the laboratory scale.

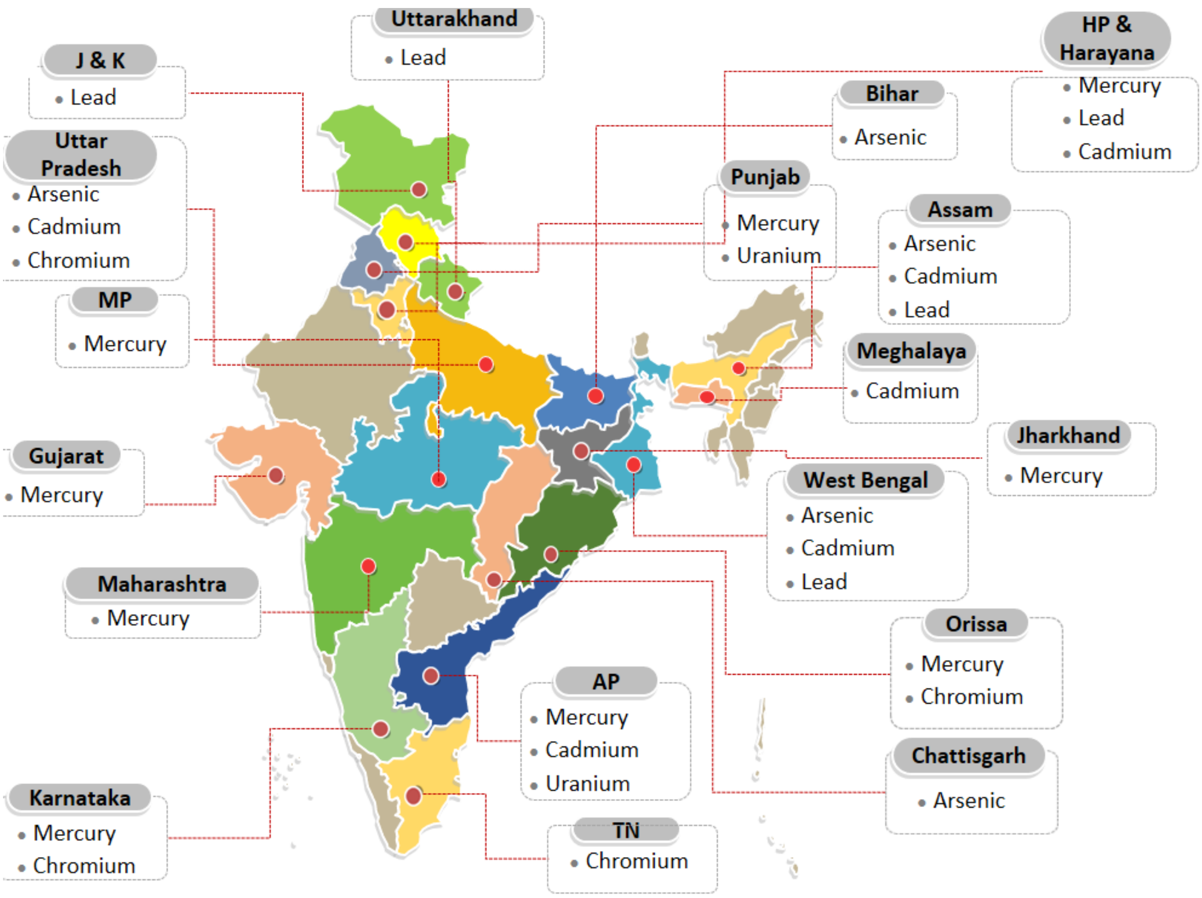

Figure 2.1. Geographical representation of heavy metal distribution (Source: Singh P et al., 2013)

2.3. Health effects of contaminants (heavy metals)

As the ground water withdrawn through mechanized process and consumed directly in most of the rural and urban place in India, a wide study on health impact were important to this aspect. For the same, in the present study, various heavy metals and their health related issues were tabulated as in table 2.3. Therefor any one can correlate with a heavy metal in a specific location and health issue very easily. As Hg, Cd and Pb are the major concern of Haryana, we can clearly draw a conclusion from the table that, there is a big chance of Kidney related issues and little bit issue with nervous and other system.

Table 2.3. Various heavy metals and their health impact

Element	**Health affects**
Arsenic	Neurological effects, obstetric problems, high blood pressure and cancers typically involving the skin, lung, and bladder.
Cadmium	Kidney Damage
Chromium	Allergic dermatitis
Mercury	Kidney Damage
Lead	Damage to the brain, kidneys, nervous system and red blood cells.
Copper	Kidney and Liver damage.
Nickel	Respiratory Failure, Heart disorders, birth defects and allergic dermatitis
Nitrate	Shortness of breath and blue-baby syndrome in children.
Fluoride	Muscle disorders, Thyroid disease, Arthritis, Dementia, Bone fractures, lowered thyroid function, Bone cancer, Genetic damage, Increased tumor and cancer rate, Damaged sperm and increased

	infertility.
Calcium	Cardiovascular disease, Growth retardation, Reproductive failure.
Copper	Kidney and Liver damage.

Table 2.4. Organic substances used to remove water contaminants

S. N.	Element	Organic Substances
01	Fluoride	Horse gram powder, Pine apple peel powder, Orange peel powder, Ragi powder, Multhani matti, Chalk powder, Red soil and concrete.
02	Cadmium	Banana Peels, Deodar cadres saw dust, Orange waste, Duckweed, Activated carbon from coconut coir pith, Spent grain, Sugar beet pulp, Ground Wheat stem, Hazelnut, Apricot, Almond, Pistachio, Walnut, Orange peels, Rice husk and Fly ash.
03	Chromium	Coffee Husk
04	Lead	Banana Peels, Spent grain, Sugar beet pulp, Cattle bone, Maple leaves ,Hazelnut, Apricot, Almond, Pistachio, Walnut, Orange peels, Rice husk and Fly ash
05	Zinc	Hazelnut, Apricot, Almond, Pistachio, Walnut, Orange peels and Banana Peels.
06	Nickel	Orange peels, Banana peels, Rice husk and Fly ash.
07	Cobalt	Banana peels and Orange peels.
08	Copper	Cuttlebone, Hazelnut, Apricot, Almond, Pistachio, Walnut, Orange

		peels, Banana peels, Rice husk and Fly ash.
09	Iron	Fly ash and Rice husk.
10	Arsenic	Litchi Pericarps.

Table 2.5. Water Contamination in India

Element	Areas Found	Sources	Health Effects	Removal Methods	Efficiency
Arsenic	Bihar, Chhattisgarh and Uttar Pradesh &Assam, WB	Mining or metallurgical operations or from runoff from agricultural areas where materials containing arsenic were used as industrial poisons.	Skin: Pigmentation changes, skin lesions and hard patches on the palms and soles of the feet (hyperkeratosis), skin cancer, cancers of the bladder and lungs, developmental effects, neurotoxicity, diabetes, pulmonary disease and cardiovascular disease.	Reverse osmosis, activated alumina, Ion exchange, Activated carbon, and Distillation.	Reverse osmosis: 90%, Ion exchange:90-100%, Activated carbon:40-70%, Distillation: 98%
Mercury	Andhra Pradesh, Haryana, Himachal Pradesh, Karnataka, Madhya Pradesh, Maharashtra , Orissa, Punjab, West Bengal, Gujarat, Jharkhand	Erosion of natural deposits; discharge from refineries and factories; runoff from landfills and croplands	Kidney damage	Activated Carbon, Reverse Osmosis	Reverse osmosis: 95-97%
Cadmium	Andhra Pradesh, Haryana, Meghalaya, UP, Assam, WB	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints, Cadmium emissions come from fossil fuel use.	Kidney damage	Sodium form cation exchanger (softener), Reverse Osmosis, Electro dialysis.	Reverse Osmosis : 95 - 98%

Element	Areas Found	Sources	Health Effects	Removal Methods	Efficiency
Lead	West Bengal, Haryana, Uttarakhand, Assam, Jammu and Kashmir	Contamination from metallurgical wastes or from lead-containing industrial poisons, corrosion of the lead solder used to put together the copper piping.	Damage to the brain, kidneys, nervous system, and red blood cells.	Activated carbon filtration, Reverse osmosis, Distillation	Reverse osmosis: 94 to 98%
Chromium	Tamil Nadu, Orissa, Karnataka, Uttar Pradesh	Discharge from steel and pulp mills; erosion of natural deposits	Allergic dermatitis, Inhalation problems	Trivalent chromium (Cr^{-3}) can be regenerated with hydrochloric acid. Hexavalent chromium (Cr^{-6}) must be regenerated with caustic soda (sodium hydroxide) NaOH. Reverse Osmosis, Distillation.	Reverse Osmosis: 90 to 97%.
Fluoride	AP, Bihar, Assam, Chhattisgarh, Delhi, Gujarat, Haryana, Jammu and Kashmir, Jharkhand, Karnataka, Kerala, Maharashtra, MP, Orissa, Punjab, Rajasthan, TN, UP, WB	Waste water from the manufacture of glass and steel, foundry operations, Organic fluorine is present in vegetables, fruits, nuts, Inorganic fluorine like sodium fluoride, is a waste product of aluminum and is used in some rat poisons.	Hyperactivity and/or lethargy, Muscle disorders,Thyroid disease, Arthritis, Dementia ,Bone fractures Lowered thyroid function, Bone cancer, Inactivates 62 enzymes and inhibits more than 100 ,Inhibited formation of antibodies, Genetic damage, Increased tumor and cancer rate, Disrupted immune system ,Damaged sperm and	Anion exchange, Adsorption by calcium phosphate, magnesium hydroxide or activated carbon and Reverse osmosis	Reverse Osmosis: 93-95%

Element	Areas Found	Sources	Health Effects	Removal Methods	Efficiency
			increased infertility		
Nitrate	Andhra Pradesh, Bihar, Delhi, Haryana, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa. Punjab, Tamil Nadu, Rajasthan, West Bengal and Uttar Pradesh.	Contamination of ground water supplies by septic systems, feed lots, and agricultural fertilizers.	Infants below the age of six months who drink water containing nitrate in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Reverse osmosis, Anion exchange resin, distillation.	Reverse osmosis: 92 - 95%

Element	Areas Found	Sources	Health Effects	Removal Methods	Efficiency
Calcium	Uttarakhand	It may dissolve from rocks such as limestone, marble, calcite, dolomite, gypsum, fluorite and apatite.	Cardiovascular disease, Growth retardation, Reproductive failure.	Simple sodium form cation exchanger (softener), Reverse Osmosis, Electro dialysis and Ultra filtration, hydrogen form cation exchanger portion of a deionizer system.	Reverse Osmosis : 95% - 98%

Table 2.6. Summative study on various water purification techniques and ultimate results

SL No.	Objective	Brief summary	Outcome	References

01	Water purification using different waste fruit cortexes for the removal of heavy metals.	The peels fruits kiwi, tangerine and banana are dried and powdered into 1mm and 2mm sized particles.50 ml waste water is taken and kept in a 250ml conical flask and 0.5g of adsorbents are added to it. It is kept in a rotary shaker for 60 min at 158rpm.The suspension was filtered, and inductively coupled plasma (ICP) was used to analyze the concentration of the different metal ions present in the filtrate.	Particles of 1mm have better adsorption than 2mm particles. Kiwi fruit cortexes gave better adsorption results compared to Banana. The order of max adsorption capacity of these metal ions for Banana was Cr < Cd < Zn and Kiwi and tangerine was Cd < Cr< Zn. Adsorption capacity was dependent on pH, adsorbent dosage and contact time. The optimum pH for adsorption of metal ions was found to be 6.0.	(Al-Qahtani 2016)
02	Adsorption of heavy metals from water using banana and orange	This paper mainly focuses on removal of Cu^{2+}, Zn^{2+}, Co^{2+}, Ni^{2+}, and Pb^{2+} from water using Banana and orange peels residues can be processed and converted to adsorbents because of their high mechanical strengths, large surface areas and great adsorption capacities. Banana and orange peels are cleaned with double distilled water, dried, crushed	It was observed that The maximum adsorption occurs at pH 6–8 for banana and orange peels and decreases on further increase in pH levels. The	(Annadurai, Juang et al. 2003)

	peels	into powder and sieved into particle sizes of 1-5mm. Sieved peels were treated separately with 0.4 mol/L NaOH, 0.4 mol/L HNO_3, and distilled water. Banana or orange peels (15 g) were soaked in 200 mL of 0.4 mol/L HNO_3 for 24 hrs. Synthetic stock solutions of $CuSO_4$, $CoSO_4$, $NiSO_4$, $ZnSO_4$, and Pb $(NO_3)_2$. are prepared. Tests were performed by agitating 0.1 g of adsorbent with 100-mL metal solution at speed of 180 rpm for duration of 24 h and centrifugation at 10,000 rpm for 20 min, the residual metal concentration was determined by an atomic absorption spectro-photometer (Varian Model 202FS).	adsorption capacity was found to be 7.97mg/g for lead, 6.88mg/g for nickel, 5.80mg/g for zinc, 4.75mg/g for copper, and 2.55 mg/g for cobalt using banana peels. It was 7.75mg/g for lead, 6.01mg/g for nickel, 5.25mg/g for zinc, 3.65mg/g for copper and 1.82 mg/g for cobalt using orange peels. Maximum adsorption was achieved at high pH, with its maximum level of lead reaching about 7.97 using banana and 7.75 mg/g using orange peels.	
03	Removal of heavy metals from wastewater using	Synthetic waste water with known concentrations of copper sulfate, nickel nitrate and iron sulfate metal solutions are made separately in double distilled water using Cu, Ni, Fe. The sorption consisted of 20 mg/l for the adsorbent dose in 10 mg/l of concentration metal (Cu, Ni, Fe) at an agitation rate of 200 rpm with an adsorbent time of 20 min at	Rice husk was found to be efficient in removing Fe, Pb and Ni. Fly ash proved to be effective in adsorbing Cu and Cd by increasing the adsorbent	(Hegazi 2013)

	agricultural and industrial wastes as adsorbents.	room temperature. The adsorbent doses of 20,30,40,50 and 60 mg/L are taken. The adsorbents and the metal ions are added and stabilized by agitating to attain pH of range 2-10. Then, the nickel, iron and copper ions in the form of copper sulfate, nickel nitrate and iron sulfate were added to the bottles to make initial concentrations of 5–30 mg/L and the bottles were further agitated for 2 or 2.5 h until equilibrium was obtained. The concentration of heavy metals was determined by an atomic absorption spectrometer.	concentration, Fe removal using rice husk increased from 68.59% to 99.25%. Pb removal with rice husk increased from 22.22% to 87.17%. Ni removal using rice husk increased from 94.885% to 96.954%. Cd removal using fly Ash increased from 25.21% to 73.54%. Cu removal using fly Ash increased from 37.38% to 98.54%. Adsorption capacity was dependent on pH, adsorbent dosage and contact time. The contact time necessary for maximum adsorption was found to be 2hrs. The pH range for heavy metal adsorption was 6-7.	
04	A laboratory study using	One kg maple leaves are taken, chopped and dried at 105 C for 24hrs, sieved and graded into <75, 75, 150 and 300 µm sizes. A solution of	10 mg/l removed 98.2% Pb(II) ions than other concentrations and	(Hossain, Ngo et al. 2014)

	maple leaves as a bio-sorbent for lead removal from aqueous solutions.	lead nitrate was prepared by dissolving an accurately weighed amount (1.598 g) of the salt in 1 L of distilled water to prepare 1 liter of 1,000 mg/l solution. Experiments were conducted in Erlenmeyer flasks containing 100 ml water with 1 to 500 mg/l of Pb(II) concentration; 0.5 g of MLP of each particle size were added and shaked at 120 rpm and at room temperature for 2 hours. **Effect of bio-sorbent doses:** Batch adsorption tests were conducted with doses of MLP from 0.01 g to 3.0 g per 100 ml solution of 1–15 mg/l of Pb(II) ion at pH 6.0, for a contact time of 120 min at room temperature. **Effect of solution pH on bio-sorption:** The effect of pH on the adsorption capacity of MLP was investigated using a 100 ml solution of 10 mg/l of Pb(II) ion and a pH range of 2.0–7.0 at room temperature. Erlenmeyer flasks were shaken for 120 min to ensure that equilibrium was reached. The mixtures were then filtered using Wattman filters and the filtrates were measured by AAS.	0.5 g Maple leaves posed higher removal for Pb(II) ions. A sharp increase in bio-sorption occurred in the pH range 2.5–4.5. The maximum bio-sorption was 98.5% for Pb(II) ions at pH 6.3. Smaller particles (<75 μm) have greater Pb(II) removal capacity.	

05	Self-purification of marine environment for heavy metals: A study on removal of lead and copper by cuttlebone.	Cuttlebone is collected from cuttle fish and washed with tap water and de-ionized water. It is dried in an oven at 105°C for 24hrs and finally ground and sieved to particle sizes between 0.3-0.7 mm. Lead and copper solutions are prepared by dissolving appropriate amounts of lead nitrate and copper nitrate pentahydrate in de-ionized water. The pH value is modified and calibrated using 0.1–1.0 M HCl and/or 0.1–1.0 M NaOH. Experiment is conducted in a batch reactor on a rotary shaker in 120 rpm at room temperature. The initial pH is maintained at 5. Experiments were carried out in three initial concentrations of metal ion to be 10, 20 and 50 mg/L and with variation of adsorbent dose in the extent of 0.1 to 1.0 g/L and constant initial ion conc. of 50 mg/L. The adsorption behavior is studied by maintaining pH at 2-7.The metal ions were measured using an atomic absorption spectrophotometer.	The maximum adsorption capacities of cuttlebone for Pb and Cu were determined to be 45.9 and 39.9 mg/g. The amounts of Pb and Cu adsorption by cuttlebone increased with increasing the solution pH, so that the highest adsorption capacities of Pb and Cu were observed in pH value of 7.0 to be 18.7 and 19.8 mg/g. The maximum uptakes of Cu and Pb were observed at pH values 5.0 and 5.5.	(Dobaradaran, Nabipour et al. 2017)

06	Adsorptive removal of Arsenic from aqueous solution by waste litchi pericarps.	Litchi pericaps are washed with tap water and ultrapure water. They are dried at 70°C and then seived through a 60 mesh seive and stored in a polyethylene bottle. A stock solution of Sodium Arsenite $NaAsO_2$ (1,000 mg/L) was prepared with ultrapure water. Polyethylene tubes of 100ml are taken with 50ml of aqueous arsenic solution. Different adsorption capacities are observed with LPs (1–20 g/L) with varying initial arsenite conc. (0.01–100 mg/L) at 293.15 K. The pH is maintained between 2-11 by using 0.1M HCl and 0.1 M NaOH solutions. The polyethylene centrifuge tubes were shaken in a vertical temperature oscillation incubator at 220 rpm for 5 to 180 min. The suspensions were filtered through 0.45 µm cellulose acetate membrane filters. Arsenic filtrates are observed through atomic absorption spectrophotometer.	The removal rate increases from 24.0% to 97.74% as the adsorbent dose increases from 1.0 to 10.0 g/L. No further increase in the removal rate of As(III) is observed for LP additions from 10.0 to 20.0 g/L. Arsenic removal efficiency increases from 88% to 93% as the contact time increases from 10 to 60 min. The removal rate increases as the pH increases from 2 to 5, and then it decreases slightly with a further pH increase from 6-7.	(Li, Qi et al. 2016)
07	Arsenic removal from aqueous solutions by adsorption on	The mud suspension was wet sieved through a 200 mesh screen and washed five times with distilled water. The last suspension was filtered and the residual solid was then dried at 105° C, ground in a mortar and sieved through a 200 mesh sieve. Stock solutions containing 1 g As(III) were prepared by dissolving 1.320 g As_2O_3 in 10 ml of 5 M NaOH and	As(III) and As(V) adsorptions are obtained within 45 and 90 min respectively, at 25°C, 133.5 µmol/L concentration and 20g/L red mud dosage. For As(III) and	(Altundoğan, Altundoğan et al. 2000)

	red mud	making up to 1 l with distilled water. $Na_2HASO4.7H2O$ salt was dissolved in water for 1g/L As(V) stock solution. Solution containing 125 to 1500 mg arsenic and 5 ml of 0.1 M NaCl solution were made to 50 ml using distilled water. The mixture of adsorbent and solution are shaken at the rate of 800 cycle/min with mechanical shaker. At the end of the contact period, the mixture was then centrifuged for 10 min at 10000 rpm.	As(V), adsorptions take places at pH 9.5 and 3.2. The adsorption densities at these conditions are 4.31 and 5.07 µmol/g for As(III) and As(V).	
08	Removal of Fluoride From Water And Wastewater By Using Low Cost Adsorbents.	Horse gram powder, Pine apple peel powder, Orange peel powder and Ragi powder are obtained from Fields, Multhani matti from Super market, Chalk powder from Class room and Red soil and concrete from construction site are obtained. 1gm of adsorbents are added to 100ml fluoride solution. Contact time for 24hrs is maintained at room temperature. The initial and final concentrations of aqueous solutions solution of fluoride and industrial waste water were determined by using spectrophotometer and fluoride removal percentage is obtained.	Removal capacities are as follows: Chalk, pine apple peel powder - 86%, Orange peel powder-79%, Horse gram seed powder-75%, Red mud-71%, Ragi powder-65%, Multani mati-56%,	(Gandhi, Sirisha et al. 2012)

			Concrete-53%.	
09	Removal of Pb (II) and Cd (II) from water by adsorption on peels of banana	Banana peels are collected and separated from fruit, washed and dried in sunlight for 5days and then in an oven at 70°C. Dried peels were cut into small pieces, ground and sieved to 60 mesh. Standard solutions of lead nitrate and cadmium nitrate are prepared using stock solutions in distilled water. Standard solutions of the desired concentrations (10–100 µg mL^{-1}) were prepared by successive dilutions of the corresponding stock solutions. Six solutions with conc. 30, 40, 50, 60, 70 and 80 µg mL^{-1} were made by proper dilution of stock solutions of lead and cadmium. pH was adjusted to 5 for lead and to 3 for cadmium. 2.0g for lead and 1.5g for cadmium weighed sorbent was added to 50 ml of each metal solution and was agitated for half an hour. Suspensions are analyzed using	Banana peels has better tendency to adsorb cadmium as compared to lead. Maximum adsorption capacity of banana peels indicates that 1 g of banana peels, can adsorb 5.71 mg of cadmium and 2.18 mg of lead. Maximum adsorption of cadmium has taken place at pH 3 and for lead, at pH 5.	(Anwar, Shafique et al. 2010)

		atomic absorption spectroscopy.		
10	Sawdust: A green and economical sorbent for the removal of cadmium (II) ions	Deodar Cedrus sawdust was obtained and passed through a 25 mesh sieve. The sawdust was washed thoroughly with deionized water and was dried at 100 ◦C. Caustic treated sawdust was prepared by mixing 5 g of sawdust with 50 ml of 1 mol/L NaOH for 2 h. Excess of NaOH was removed with water and the material was dried at 100°C for 8 h. Three S/L (solid sorbent/liquid) ratios 1/20, 1/10, and 1/5 were used containing 0.01M $NaNO_3$were added to each of the bottles. pH range is adjusted from 2 to 12 and shaken for 24 h under closed conditions.	The metal ions were eluted with 0.1 mol/L HCl and determined by AAS. This shows the use of waste material for the pre-concentration of toxic Cd (II) metal ions. The main advantages of procedure are ease and simplicity of preparation of the sorbent, sensitivity; and rapid attainment phase equilibration & good enrichment.	(Memon, Memon et al. 2007)
11	Removal of cadmium from aqueous solutions by adsorption	The orange waste was first cut into small pieces, was washed with tap water to remove adhering dirt and then was oven dried at 50-60° C until constant weight. The washed and dried material was crushed and sieved to obtain a particle size lower than 1.5 mm. Stock cadmium solution was prepared by dissolving 2 g of analytical grade cadmium metal in a	Cadmium uptake is highly affected by pH. When the pH was increased from 2 to 6, the percentage of cadmium uptake for a cadmium solution of 100 mg/l	(Pérez-Marín, Zapata et al. 2007)

	onto orange waste	mixture of 50 ml of distilled water and 10 ml of concentrated nitric acid, and diluting to a litre with distilled water. The mixture was stirred magnetically for 3 h. The pH of solutions was adjusted by adding dilute solutions of HNO_3 and NH_4OH. Experiments were carried out with different particle size fraction (<0.3, 0.3–0.5, 0.5–0.8, 0.8–1, 1–1.25, 1.25–1.5, 1.5–2.5 mm). A 0.2 g of biomass was added to glass flasks containing 50 ml of metal solution (100 mg/l). The mixture was stirred magnetically for a contact time of 3 h, at room temperature and at pH 4. The effect of adsorbent dosage on sorption of Cd was obtained by agitating 50 ml of metal solution (100 mg/l) with 0.0125, 0.025, 0.05, 0.075, 0.1, 0.15, 0.2, 0.25, 0.3 and 0.4 g of adsorbent for 3 h at room temperature and at constant pH 4.	rose from 8 to 98%. The adsorption kinetic is rapid and the equilibrium can be considered to be reached at 60 min, at pH values of 4-6.	
12	Activated carbon from coconut coirpith as metal adsorbent:	Waste coirpith was collected from coir processing and dried in sunlight. The stock solution of 1000 mg/L of Cd(II) was prepared from cadmium sulfate ($CdSO_4.8H_2O$) in distilled water containing a few drops of nitric acid to prevent hydrolysis. The stock solution was diluted as required to obtain standard solutions containing 5–40 mg/l Cd(II). Adsorption studies were carried out with 20 mg of adsorbent and 50 ml of Cd(II)	Equilibrium adsorption was established within 40 min for 10 mg/l Cd(II), 50 min for 20mg/l Cd(II) and 60 min for 30 and 40 mg/l Cd(II). The adsorption rates depend on concentration and pH.	(Kadirvelu and Namasivayam 2003)

	adsorption of Cd(II) from aqueous solution	solution of desired concentration at an initial pH of 5.0 in 100-ml conical flasks, which were agitated at 160 rpm for time intervals at room temperature on a mechanical shaker and were centrifuged at 8600rpm. Adsorption isotherm studies were carried out with eight different initial concentrations of Cd(II) from 5 to 40 mg/l while maintaining the adsorbent dosage at 20 mg/50 ml. The effect of adsorbent dosage on percent removal was studied using Cd(II) concentrations of 20 and 40 mg/l.	The adsorption capacity was 93.4 mg/g Cd(II) at initial pH 5.0 for the particle size 250–500 µm.	
13	Equilibrium isotherm studies for the uptake of cadmium and lead ions onto sugar beet pulp.	The waste pulp of sugar beet remaining from extraction of sugar was used as Pb^{2+} and Cd^{2+} ion bio-sorbents. The pulp was obtained and washed with tap water to remove soil and dust, sprayed with distilled water and then dried in an oven at 100°C to a constant weight. The (SBP) was dried, grinded and sieved the particle sizes distribution of 150 200µm. The (SBP) was washed with 1.0 M HCl and distilled de-ionized water until a constant pH was achieved. The batch tests were conducted for the equilibrium time mixing at a constant speed of 200 rpm after adjusting the pH to the optimum value for maximum adsorption.	Metal sorption is pH-dependent and maximum sorption for Cd^{2+} and Pb^{2+} was found to lie between 5.0 and 5.3. Metal adsorption is very quick at the different conc. studied under the experimental conditions used. The maximum metal sorption capacity of bio-sorbents was 46.1 mg g/L for Cd^{2+} and 43.5 for Pb^{2+} ion at 25°C. The amount of Cd^{2+} and	(Pehlivan, Yanık et al. 2008)

		Various initial metal concentrations were prepared by serial dilution of 1000 ppm of standard solution of metals. pH maintained in range from 2 to 7. The test tubes were sealed with caps and placed on the thermostatic shaker. The test tubes were removed after 24 h shaking of the solution and centrifuged for 5 min at 3000 rpm. The solution was analyzed using AAS finally.	Pb^{2+} adsorbed by the (SBP) increased with the increase in concentration. The extent of adsorption for both metals increased along with an increase of the (SBP) dosage.	

Chapter 3
Research Methodology

To fulfill the main purpose of the present study, a wide range of research work has been carried out and methodologies of every steps were designed with consideration of output of previous steps respectively. Although the main focus was design, fabrication and performance evaluation of low budget drinking water filter for rural areas of state Haryana, but it has been also considered to assess quality of ground water of various locations of the state and relevant health issues associated with sensitive parameters. Methodologies also deals with the way of searching best adsorption trick to encounter various heavy metals and considerable ions. A method also adopted for cost analysis with consideration of installation, operation and maintenance. The details of individual research method mentioned step by step as below:

3.1. Methodology for assessment of ground water quality and relevant health issues

3.1.1. Assessment of Ground water Quality

Before suggesting any treatment options for quality drinking water, it is very essential to assess the ground water quality of same location. As the present study deals with treatment options for rural areas of state Haryana, wide range of literatures, parameters, standards etc. were studied with consideration of the same locations. Mythology adopted for the assessment of ground water quality based on Literature survey and based on laboratory analysis mentioned elaborately in section 3.1.1.1 and 3.1.1.2

3.1.1.1. Water quality assessment through literature survey

Most challenging part of assessment of ground water quality through literature survey is non-uniformity in available data. A wide range of literature from various sources has been studied and was found that targeted locations, targeted pollutants, number of parameters, analysis techniques etc. of various studies are different.

To avoid confusion in data assessment, all the parameters considered in literatures has been enlisted along with reported minimum and maximum values. The detailed data about the same has been reported in result section.

3.1.1.2. Water quality assessment through laboratory analysis

A wide range of ground water were collected from various locations of Haryana as mentioned in table for the laboratory analysis. Sampling locations were pointed on map clearly for better understanding of distribution of sampling sources of the state, as shown in Figure. A total of 11 quality parameters were assessed in the laboratory as shown in Table 3.1. All analyzed data has been reported in terms of table with consideration of targeted quality parameters.

Table 3.1. Source of samples for laboratory analysis

Location	District	Source of sample
1	Ambala	Govt. Girls Sr. Sec. School Model Town, Ambala City
2	Faridabad	Govt. Middle School Sector 31, Faridabad
3	Gurgaon	Govt. Model Sanskriti Sr. Sec. School
4	Hisar	Govt. Sr. Sec. School, Jahaj Pul, Hisar
5	Kaithal	Hindu Girls Senior Secondary School
6	Kurukshetra	Govt school Birpipli Kurukshetra
7	Panipat	Govt. High school weavers colony panipat
8	Rohtak	Rainakpura Govt. School Rohtak

Figure 3.1. Location of sample collection on map

Table 3.2. Considerable water quality parameters for laboratory analysis

	pH	Turbidity (NTU)	Total Alkalinity (mg $CaCO_3$/L)	Total Hardness (mg $CaCO_3$/L)	TDS (mg/L)	Chloride (mg/L)	Fluoride (mg/L)	Cadmium (µg/L)	Lead (µg/L)	Hg (µg/L)	Total Chromium (µg/L)
Acceptable limit as per IS 10500 : 2012	6.5-8.5	1	200	200	500	250	1	3	10	1	5

3.1.2. Assessment of Relevant health issues

It is very important to assess various health issues due to drinking water of targeted source. Local peoples of various locations of Haryana state are facing wide range of health related diseases knowingly or unknowingly. The reason behind all diseases may or may not be the poor quality of drinking water but in the present study, sensitive parameters those are present in groundwater beyond the prescribed range, their health related were studied and surveyed as below mentioned steps.

3.1.2.1. Assessment of health issues through Literature survey

The result from laboratory analysis on ground water quality were considered to find out relevant health issues. A tabulated information on quality parameter (those are above prescribed level) and there probable health problems.

3.1.2.2. Assessment of health issues through field survey

The place where comparatively worst quality of ground water available, a field survey were carried out on actual health problem they are facing during too poor drinking water consumption. For the same, 65 families of 4 villages of Gurgaon district were selected randomly as shown in table 3.3.

Table 3.3. Overall survey plan and execution

Village Targeted in Gurgaon District	Number of family	Total member	Date of Survey
Nainwal	15	66	27th Dec 2018
Chakkarpur	20	81	28th Dec 2018
Samaspur	15	70	3rd Jan 2019
Patli Hajipur	15	72	4th Jan 2019
Total	65	289	

3.2. Methodology for optimization of suitable adsorption technique

3.2.1. Methodology for Selection and Preparation of adsorbent material

3.2.1.1. Selection of Bio-Adsorbent

- Literatures were reviewed on various bio-adsorbents and their pollutants of interests.

- Based on the result of laboratory analyzed characteristics of untreated drinking water, sensitive parameters (especially heavy metals and ions) were targeted.

- Selected effective bio-adsorbents those can encounter targeted heavy metals and ions.

3.2.1.2. Collection of bio-Adsorbent

- Based on previous analysis it was found that Cd, Pb and F- are targeted pollutants and Orange peels, Sugarcane husk, and Rice husk are effective bio-adsorbents.

- Collected Orange peels, Sugarcane husk, and Rice husk from various sources in plastic bags on the same day of generation.

- To avoid decomposition of bio-adsorbents, adsorbents were washed properly with tap water, Sun-dried and stored in dark and dry place on same day

- Figures mentioned below shows collected bio-adsorbents.

Figure 3.2. Clean and dry Orange peel

Figure 3.3. Clean and dry Sugarcane husk

Figure 3.4. Clean and dry Rice husk

3.2.1.3. Preparation of bio-Adsorbent

- Dried at 103 degree C for 3 hours in oven drier to eliminate maximum moisture present in the adsorbents media and to make the same crushable.

- Cooled down the materials and Crushed using mechanical crusher very gently to ensure presence of various size ranges.

- Screened the crushed material using sieve analyzer and segregated in size group of 250, 500, 750 and 1000 micro meter.

- Stored segregated adsorbents media in plastic containers in clean, dark and dry place with proper tags.

3.2.2. Methodology – Treatment of targeted water using Adsorption process

3.2.2.1. Calculation of adsorbent dose

- 250 ml of untreated water were taken for individual experiments for the optimization of other inputs and to ensure availability of water after sampling for final analysis.

- To optimize adsorbent dose a range from 1 g/L to 10 g/L of various adsorbents were added in step by step.

- Amount of adsorbents in terms of gram were calculated with appropriate ratio as shown in table 3.4.

Table 3.4. Amount of adsorbent at various experiments

Adsorbent dose (g/L)	Actual weight of adsorbent (g)	Untreated water taken (ml)
1	0.25	250
2	0.5	250
3	0.75	250
4	1	250
5	1.25	250
6	1.5	250
7	1.75	250
8	2	250
9	2.25	250
10	2.5	250

3.2.2.2. Set-up adsorption process

- All the experiments were carried out in 500 ml beaker placed on flat plate magnetic starrier in laboratory

- 250 ml untreated water without changing initial pH were taken in beaker and calculated adsorbent amount were used to observe changes in characteristics of water.

- To ensure complete adsorption an observation of 30 minute duration considered for all the experiments. It was observed that most of the cases within 2.5 minutes maximum adsorption takes place.

- To enhance mixing of adsorbent and water a speed of 500 rpm was maintained in magnetic stirrer throughout all the experiments.

- Total number of 90 experiments were conducted to find out removal trend of targeted pollutants with various adsorbents and their sizes. A summary of experiment shown in table 3.5 mentioned below:

Table 3.5. Experiment Summary with size of adsorbents

Targeted Pollutant	Orange peels	Rice husk	Sugarcane husk
Cd	500 µm, 750 µm and 1000 µm	500 µm, 750 µm and 1000 µm	500 µm, 750 µm and 1000 µm
Pb	500 µm, 750 µm and 1000 µm	500 µm, 750 µm and 1000 µm	500 µm, 750 µm and 1000 µm
F^-	500 µm, 750 µm and 1000 µm	500 µm, 750 µm and 1000 µm	500 µm, 750 µm and 1000 µm

3.2.2.3. Collection and storage of treated water

- After the adsorption a settling time 30 minutes were allowed for each experiment, to ensure no adsorbents are present in sampled water.

- Gently, 100 ml of water collected in a 250 ml conical flask from top level of beaker using pipet to avoid agitation and mixing of settled sludge.

- Most of the cases, immediate analysis were conducted post adsorption. If not possible to analyze the sample on same day, same were carefully covered, tagged and stored at 3 degree C for further analysis.

3.3. Methodology for design and performance evaluation of treatment unit

3.3.1. Innovative steps design

- To optimize overall cost of operation and maintenance, innovative steps were designed. The same time steps has been made for maximum treatment efficiency.

- Columns and inner pipes placed in such a way, it not requires external driving force but through gravitational force.
- Orange peel column, Rice husk column and sugarcane husk column attached in series to eliminate all targeted pollutants then passes through settling tank to allocate enough time for gravity settlement.

3.3.2. Calculation of Design specifications

- Specification of columns, pipes, inlet, outlet, height, flow rate, retention time were calculated using rational formulae as shown in results.
- Calculate amount of adsorbent need to pack in various column based on column size. Same calculation and amount discussed in results.
- Calculate column refill duration based on adsorption capacity of various media and per family drinking water demand. Details calculations and final values mentioned in results.

3.3.3. Performance Evaluation

- Analyzed quality parameter of treated water (water passes through whole the process). Same quality parameters as mentioned in section 3.1.1.2 were analyzed.
- Individual analysis repeatedly done for a minimum of 3 times to avoid errors in calculated results.
- Analyze the performance efficiency by comparing calculated values with standard values and initial characteristics.

3.4. Methodology for water wastage ratio and cost analysis

3.4.1. Estimation of water wastage ratio

- A separate experiment was carried out to check water wastage ratio on the basis of amount of input and output water for conventional RO unit and designed water treatment unit. Experiment details has been mentioned in below points.

- At saturated condition 1 L of water was taken as sample input and the output amount measured in measuring cylinder. Then calculated water wastage ratio.

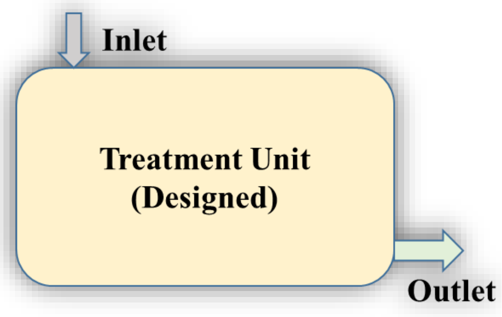

Figure 3.5. Inlet and outlet of designed treatment unit

Condition of treatment unit: Saturated

Apparatus used: measuring cylinder

Input sample water: 1 L

Output sample collected and measured: 1 L

Repetitions of experiment: 3 times

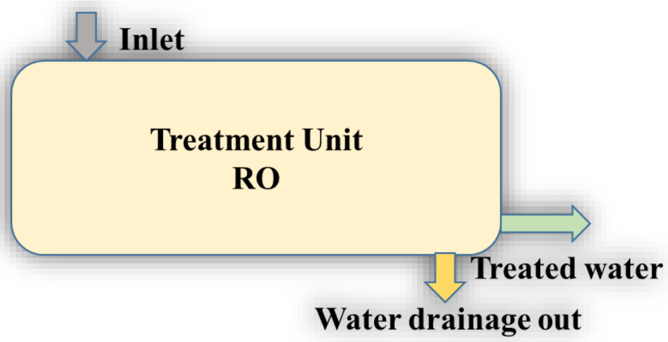

Figure 3.6. Inlet and outlets of conventional RO unit

Condition of treatment unit: Saturated

Apparatus used: measuring cylinder

Treated water level increased: 1 L

Drainage water collected and measured: 4.15 L (Average)

Repetitions of experiment: 3 times

3.4.2. Cost Analysis

- With the help of values from design criteria and viability of same in the market, specification of all raw materials considered.

- To make uniformity in price of individual materials and to avoid confusion in fluctuation in market values, cost of raw materials were calculated on the basis of wholesale price from www.alibaba.com (dated 24 August, 2020).

- Fabrication and labor cost were considered on the basis of fabricator wage (North India) and Labor Wage (North India) respectively as prescribed in document of Labor commissioner of India guideline.

- Cost required for Adsorbents were considered as NIL because Orange peel, rice husk and sugarcane husk are bio-waste (freely available).

- As the system operates through gravity flow there is no power requirement. So, operation were cost considered to be zero.

- Cost of maintenance requires as same as Cost required for Adsorbent preparation and packing.

Chapter 4
Results and Discussion

4.1. Results for assessment of ground water quality and relevant health issues

Results over assessment of ground water quality and their relevant health issues are elaborated in section 4.1.1, 4.1.2, 4.1.3 and 4.1.4. Along with results of mentioned sections, clear discussions also added.

4.1.1. Ground water quality based on Literature survey

As the method of analysis and targeted locations were different in various research papers, heterogeneous results were obtained. To represent a clear picture about the ground water quality of state Haryana, minimum and maximum value of each parameter were reported in table (in a range). Mainly quality parameters like pH, Turbidity (NTU), Total Alkalinity (mg $CaCO_3$/L), Total Hardness (mg $CaCO_3$/L), TDS (mg/L), Chloride (mg/L), Fluoride (mg/L), Cadmium (µg/L), Lead (µg/L), Hg (µg/L) and Total Chromium (µg/L) were focused while assessed through literature survey. Values with respect to minimum and maximum ranges of each parameters has represented in table 4.1. To compare with the standard value of each parameter Acceptable limit as per IS 10500: 2012 also provided in the same table.

Value range of Fluoride (mg/L), Cadmium (µg/L), Lead (µg/L), Hg (µg/L) were clearly observed a more than the standard value and it requires a great concern as listed parameters are mainly heavy metals and ions.

Table 4.1. Ground water quality obtained from Literature survey

	pH	Turbidity (NTU)	Total Alkalinity (mg $CaCO_3$/L)	Total Hardness (mg $CaCO_3$/L)	TDS (mg/L)	Chloride(mg/L)	Fluoride (mg/L)	Cadmium (µg/L)	Lead (µg/L)	Hg (µg/L)	Total Chromium (µg/L)
Acceptable limit as per IS 10500 : 2012	6.5-8.5	1	200	200	500	250	1	3	10	1	5
Overall Quality of water	5.8 – 8.7	0.1-0.85	110-375	135-340	105-780	16.5-155	0.15-1.75	0.1-3.45	0.35-12.35	0-1.15	0-3.76

4.1.2. Ground water quality based on Laboratory analysis

Same parameters, as observed in literature, were analyzed in the laboratory as well. A total of 8 location in random 8 districts of Haryana were considered and analyzed. The ground water quality obtained from laboratory analysis represented in table 4.2. Out of all the locations, Gurgaon water quality were found to be worst. Values of Fluoride (mg/L), Cadmium (µg/L), and Lead (µg/L) were found to be 1.75, 5.25 and 14.65 respectively.

Table 4.2. Ground water quality obtained from Laboratory analysis

			pH	**Turbidity (NTU)**	**Total Alkalinity (mg CaCO3/L)**	**Total Hardness (mg $CaCO_3$/L)**	**TDS (mg/L)**	**Chloride (mg/L)**	**Fluoride (mg/L)**	**Cadmium (µg/L)**	**Lead (µg/L)**	**Hg (µg/L)**	**Total Chromium (µg/L)**
Acceptable limit as per IS 10500 : 2012			**6.5-8.5**	**1**	**200**	**200**	**500**	**250**	**1**	**3**	**10**	**1**	**5**
Govt. Girls Sr. Sec. School Model Town,	Location 1	Ambala	8.2	0.4	337	312	105.5	36.1	1.65	3.07	11.42	BDL	BDL

Ambala City													
Govt. Middle School Sector 31, Faridabad	Location 2	Faridabad	7.6	0.7	524	497	85.7	45.8	0.82	1.94	9.46	BDL	BDL
Govt. Model Sanskriti Sr. Sec. School	**Location 3**	**Gurgaon**	**7.6**	**0.5**	**598**	**578**	**135.2**	**52.5**	**1.75**	**5.25**	**14.65**	**BDL**	**BDL**
Govt. Sr. Sec. School, Jahaj Pul, Hisar	Location 4	Hisar	7.9	0.8	544	517	94.8	39.7	0.86	1.58	5.85	BDL	BDL

Hindu Girls Senior Secondary School	Location 5	Kaithal	7.8	0.4	402	378	87.4	41.3	0.74	1.78	9.03	BDL	BDL
Govt school Birpipli, kurukshetra	Location 6	Kurukshetra	7.8	0.5	437	410	98.5	40.8	0.85	2.04	6.54	BDL	BDL
Govt. High School Weavers Colony Panipat	Location 7	Panipat	7.5	1	514	482	112.8	48.2	1.08	4.12	10.08	BDL	BDL
Rainakpura Govt. School Rohtak	Location 8	Rohtak	8.1	0.5	421	392	120.5	38.7	0.96	1.96	4.28	BDL	BDL

4.1.3. Assessment of health issues through Literature survey

A wide range of health related issues were studied through various literature and same has been shown in table 4.3. Various parts of human body can be effected due to targeted pollutant were clearly shown in Figure 4.1. Main health related problem were found to be Kidney Damage, Damage to the brain, nervous system issue, red blood cells related issue, Muscle disorders, Thyroid disease, Arthritis, Dementia, Bone fractures, Bone cancer, Genetic damage, Increased tumor and cancer rate, Damaged sperm and increased infertility, Cardiovascular disease, Growth retardation, and Reproductive failure.

Table 4.3. Various elements present in ground water and their health issues as per Literature survey

Element	Health affects
Arsenic	Neurological effects, obstetric problems, high blood pressure and cancers typically involving the skin, lung, and bladder.
Cadmium	Kidney Damage
Chromium	Allergic dermatitis
Mercury	Kidney Damage
Lead	Damage to the brain, kidneys, nervous system and red blood cells.
Copper	Kidney and Liver damage.
Nickel	Respiratory Failure, Heart disorders, birth defects and allergic dermatitis
Nitrate	Shortness of breath and blue-baby syndrome in children.
Fluoride	Muscle disorders, Thyroid disease, Arthritis, Dementia, Bone fractures, lowered thyroid function, Bone cancer, Genetic damage, Increased tumor and cancer rate, Damaged sperm and increased infertility.
Calcium	Cardiovascular disease, Growth retardation, Reproductive failure.

Source: Nabipour, et al. (2017), Pérez-Marín, A., V. M. Zapata, et al. (2007)

Source: URL – 1

Figure 4.1. Various targeted body parts – drinking water related issue

4.1.4. Assessment of health issues through field survey

Randomly four villages of Gurgaon district were considered for health survey for better understanding of drinking water quality. A wide range of data includes number of family members and various heath related issues they are facing currently, and same were reported in table 4.4.

Table 4.4. Actual field data from field survey over relevant health issue

Village in Gurgaon district	Family	Number of Member in the family	Kidney Damage (kedney related issue)	Damage to the brain (Brain related issue)	Damage to the nervous system (nerves system related issue)	Anemia (RBC related issue)	Muscle Disorder (muscle pain etc.)	Thyroid disease (TSH related issue)	Infertility	Cancer
Nainwal	1	5	2	0	0	0	0	1	0	0
	2	4	1	0	0	0	0	0	0	0
	3	6	0	0	1	0	0	0	0	0
	4	3	0	0	0	0	1	0	0	0
	5	4	1	0	0	0	0	1	0	0
	6	4	0	0	1	0	0	0	0	0
	7	3	1	0	0	0	1	0	0	1

	8	5	2	0	0	0	0	0	0	0
	9	7	2	0	0	0	0	1	0	0
	10	3	0	0	0	0	0	0	0	0
	11	4	0	0	0	1	2	0	0	0
	12	6	1	0	0	0	0	0	0	0
	13	3	0	0	0	0	0	1	0	0
	14	5	1	1	0	0	0	0	0	0
	15	4	1	0	0	0	2	0	0	0
	16	5	0	0	1	0	0	0	0	0
	17	2	0	0	0	0	0	0	0	0
	18	3	1	0	0	0	1	1	0	0
	19	4	2	0	0	0	0	0	0	0
	20	4	1	0	0	2	0	0	0	0
	21	4	0	0	0	0	2	0	0	0
	22	5	2	0	0	0	0	0	0	1
	23	3	0	0	0	0	0	1	0	0
	24	5	1	0	0	0	1	0	0	0
Chakkarpur	25	4	1	0	0	0	0	1	0	0
	26	6	2	0	0	2	1	0	0	0
	27	2	0	0	0	0	0	0	0	0
	28	4	1	0	0	0	0	0	0	0
	29	5	1	0	0	0	1	1	0	0
	30	3	1	0	0	2	0	0	0	0
	31	2	1	0	0	0	0	0	0	0
	32	4	0	0	0	0	0	0	0	0
	33	6	2	0	0	0	1	1	0	0
	34	6	0	1	0	1	0	0	0	0
	35	4	1	0	0	0	0	0	0	0
	36	4	2	0	0	0	2	0	0	0
	37	7	1	0	0	0	0	1	0	0
	38	3	0	0	0	1	1	0	0	0
	39	4	0	0	0	0	0	0	0	0
	40	2	0	0	0	0	0	0	0	0
	41	6	0	0	0	0	2	0	0	0
	42	5	0	0	0	0	0	0	0	0
Samaspur	43	6	1	1	0	0	0	0	0	0
	44	5	2	0	0	1	1	0	0	0
	45	5	0	0	0	0	0	0	0	0
	46	6	1	0	0	0	0	0	0	0
	47	7	3	0	0	0	1	0	0	0
	48	3	0	0	0	1	0	1	0	0
	49	4	1	0	0	0	0	0	0	0
	50	3	1	0	0	0	1	0	0	0
	51	5	0	0	1	0	0	0	0	0
	52	4	2	0	0	0	1	1	0	0
	53	2	0	0	0	1	0	0	0	0
	54	3	0	0	0	0	0	0	0	0
Patli Hajipur	55	6	1	0	0	0	1	0	0	0
	56	4	1	0	0	0	0	0	0	0
	57	7	3	1	0	1	0	0	0	0
	58	4	0	0	0	0	2	0	0	0
	59	3	1	0	0	0	0	0	0	0
	60	6	0	0	0	0	0	1	0	0

	61	5	1	0	0	1	2	0	0	0
	62	4	0	0	1	0	0	0	0	0
	63	6	1	0	0	0	1	0	0	0
	64	7	2	0	0	0	0	0	0	0
	65	6	0	0	0	0	0	0	0	0
	Total	**289**	**53**	**4**	**5**	**14**	**28**	**13**	**0**	**2**

A total of 65 family were studied which includes total of 289 family members of various age groups and collected data were analyzed. In figure 4.2. a clear representation drawn against number of patents and various health issues. From the analyzed data it was found that mostly Kidney related and muscle related disease are being faced by local people and it was 53 and 28 in number respectively .

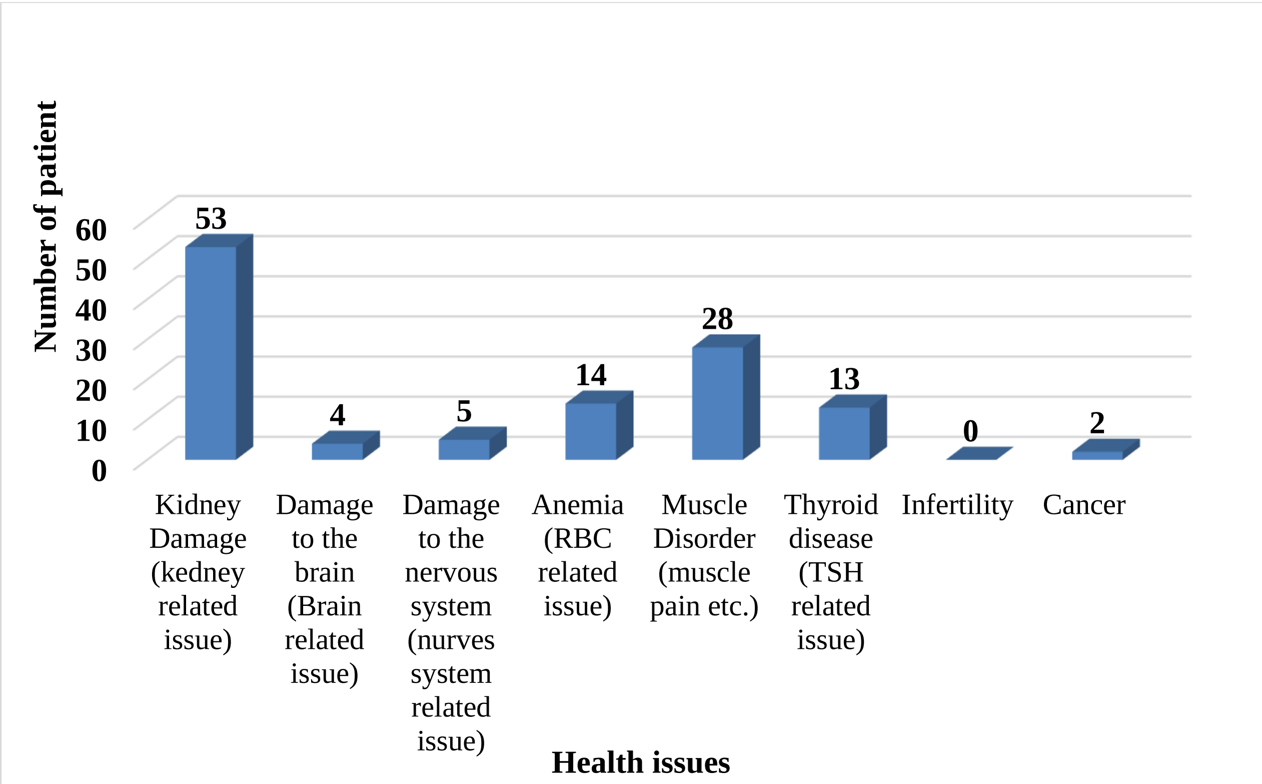

Figure 4.2. Number of Patients Vs various health issues

People those are facing kideney related issues, only they are aware about there diesis and it was accounted as 45.5%. It was very scary that 54.5% people are not aware about drinking water related issue they are carring in their daily life. The same statistics has been clearsy described in Figure 4.3.

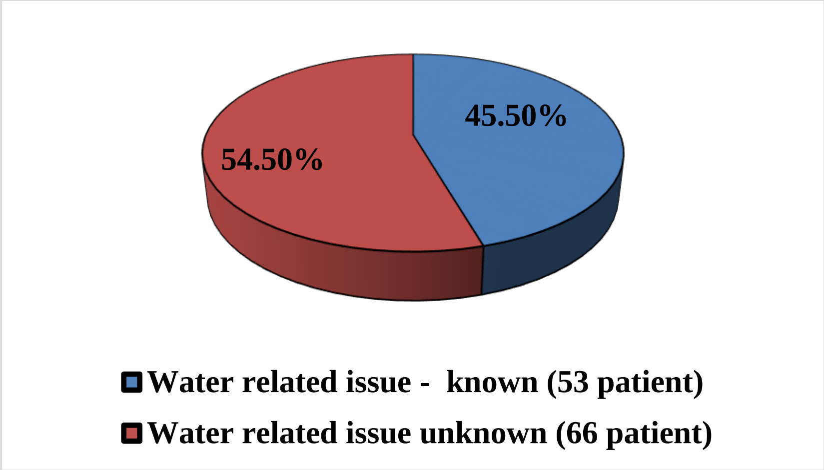

Figure 4.3. Awareness about drinking water related health issues

4.2. Results for optimization of suitable adsorption technique

Targeted pollutants were Cd, Pb and fluoride and targeted adsorbents were orange peels, sugarcane husk and rice husk for optimization of adsorption technique. A size range from 500 µm to 1000 µm were taken for each and every cases. Ground water of Gurgaon location were taken as inlet for all the experiment with consideration of worst water quality out of all 8 locations. Various sections from 4.2.1 to 4.2.9, clearly describes removal trends of pollutants with various combination of adsorbents and their doses.

4.2.1. Removal of Cd using orange peels adsorption

Water sample with Cd concentration 5.25 µg/L were taken to treat against orange peel adsorption process. Intension of the treatment was bring down the concentration below its prescribed range and that was 3 µg/L. in step by step procedure 500 µm, 750 µm and 1000 µm sizes of orange peels with dose range from 1 g/L to 10 g/L were taken to get optimum value. For the experiments it was observed that orange peels works great to encounter Cd concentration from water sample. It was found to be 500 µm size of adsorbents works better than other two sizes because of more surface area to adsorb. At 2 g/L dose, 500 µm size of adsorbents can reduce the value below the standard concentration. To make the confident optimum dose, 3 g/L were considered the best one. The detailed result over this experiments clearly represented in figure 4.4.

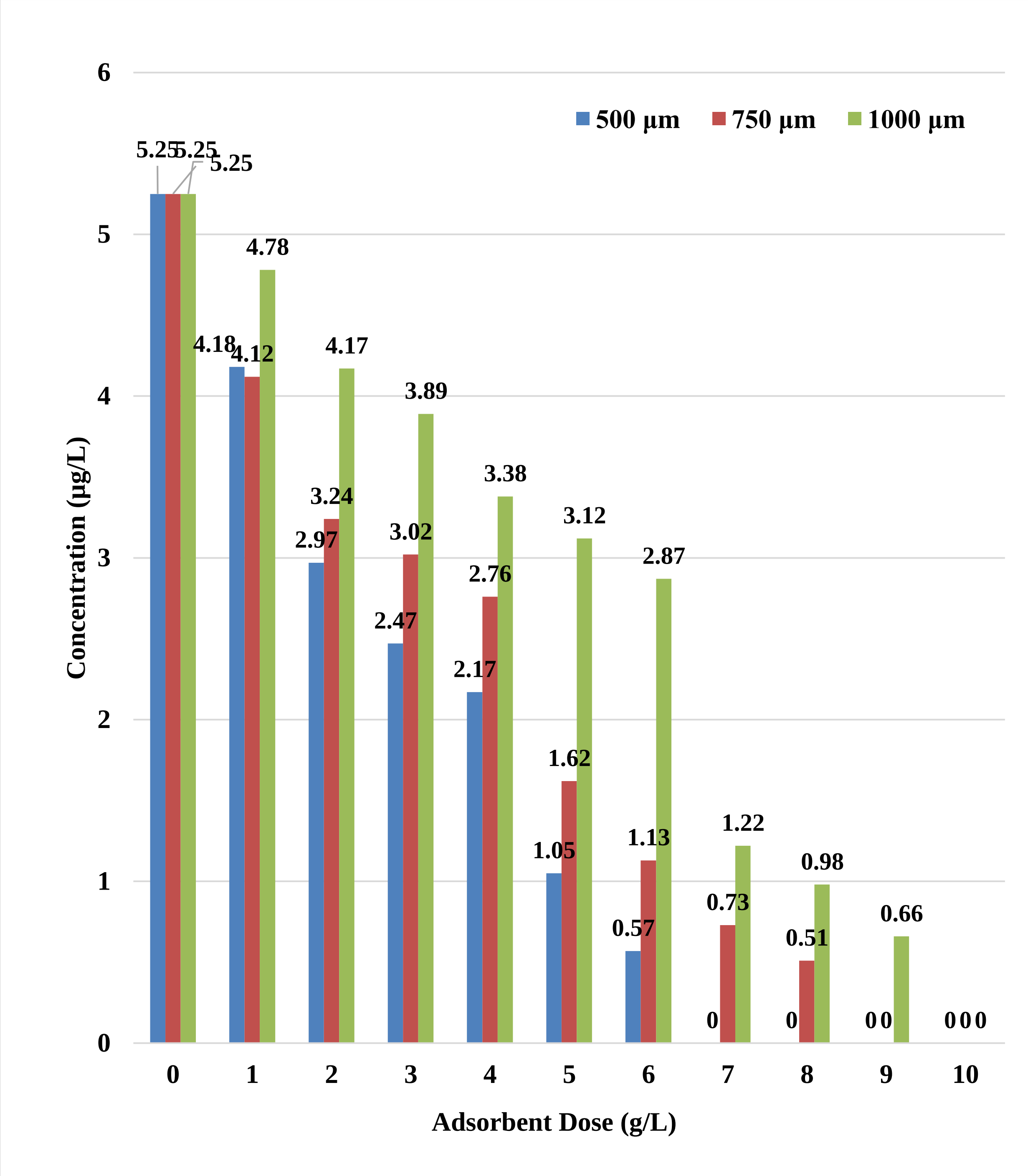

Figure 4.4. Removal of Cd using orange peels adsorption

4.2.2. Removal of Cd using Sugarcane husk adsorption

Water sample with Cd concentration 5.25 µg/L were taken to treat against sugarcane husk adsorption process. Intension of the treatment was bring down the concentration below its prescribed range and that was 3 µg/L. in step by step procedure 500 µm, 750 µm and 1000 µm sizes of orange peels with dose range from 1 g/L to 10 g/L were taken to get optimum value. For the experiments it was observed that sugarcane husk works not that great to encounter Cd concentration from water sample. It was found to be 500 µm size of adsorbents works better than other two sizes because of more surface area to adsorb. At 7 g/L dose, 500 µm size of adsorbents can reduce the value below the standard concentration. The detailed result over this experiments clearly represented in figure 4.5.

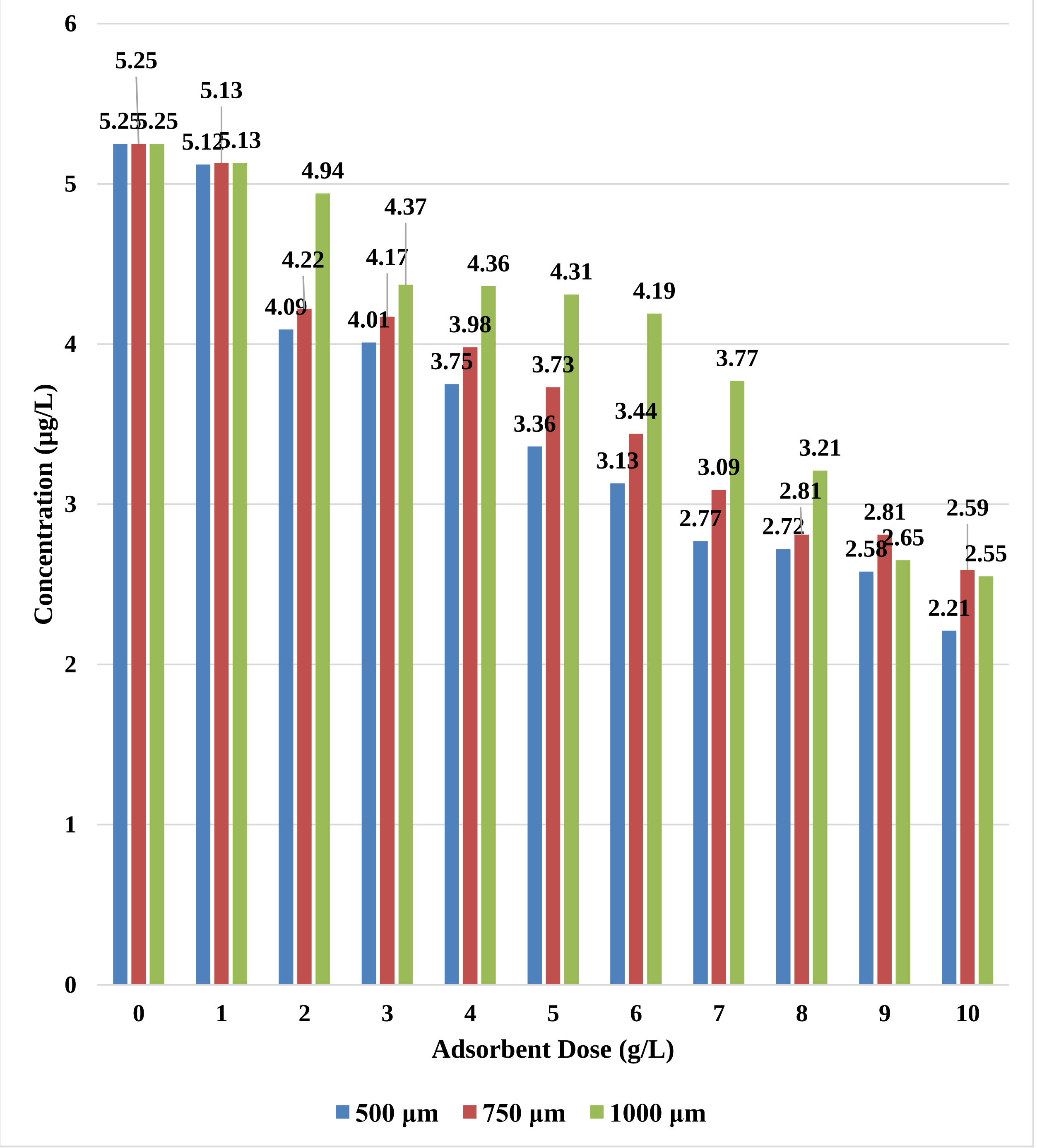

Figure 4.5. Removal of Cd using Sugarcane husk adsorption

4.2.3. Removal of Cd using Rice Husk adsorption

Water sample with Cd concentration 5.25 µg/L were taken to treat against rice husk adsorption process. Intension of the treatment was bring down the concentration below its prescribed range and that was 3 µg/L. in step by step procedure 500 µm, 750 µm and 1000 µm sizes of orange peels with dose range from 1 g/L to 10 g/L were taken to get optimum value. For the experiments it was observed that rice husk works not that great as orange peels to encounter Cd concentration from water sample. It was found to be 500 µm size of adsorbents works better than other two sizes because of more surface area to adsorb. At 4 g/L dose, 500 µm size of adsorbents can reduce the value below the standard concentration. The detailed result over this experiments clearly represented in figure 4.6.

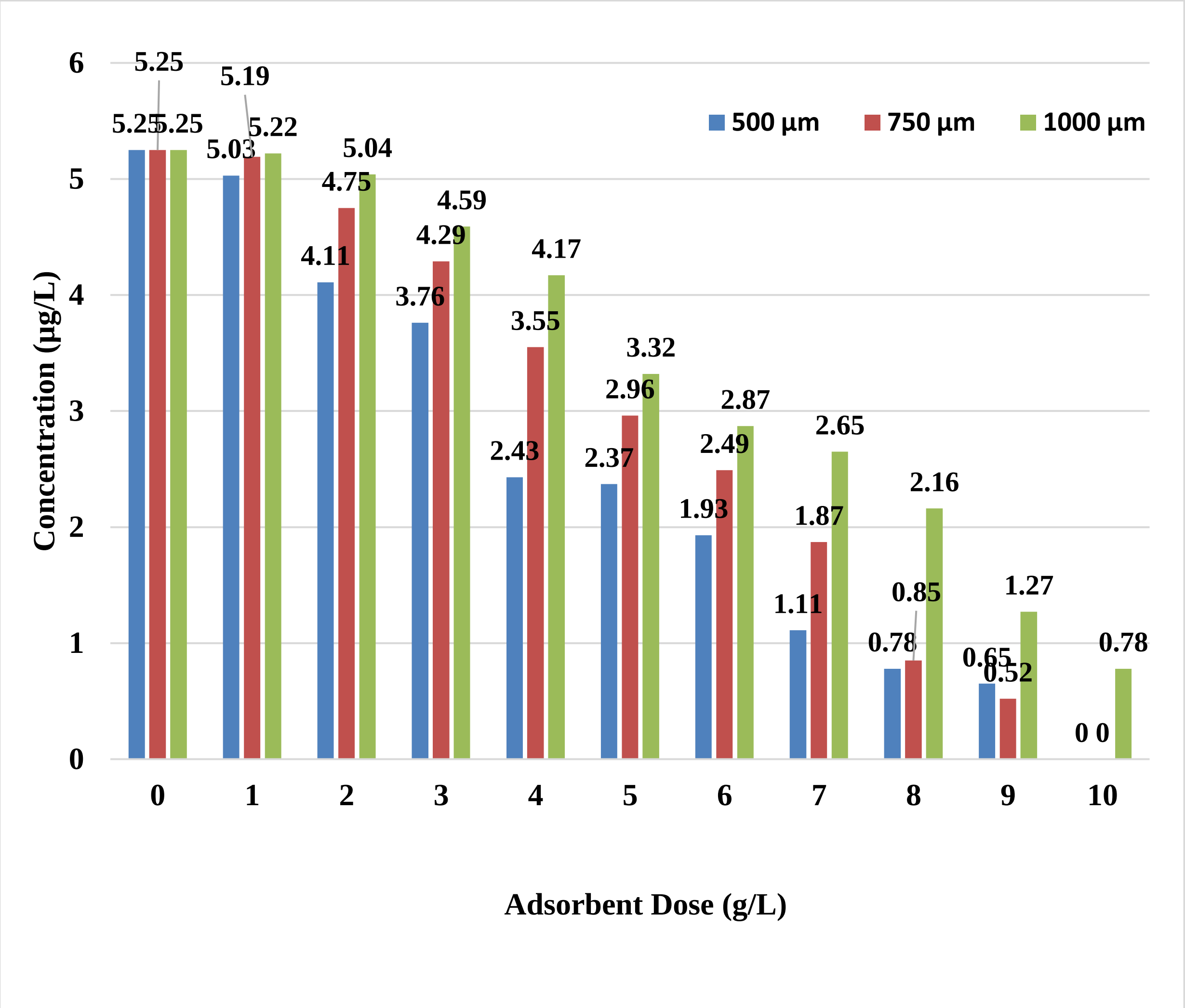

Figure 4.6. Removal of Cd using Rice Husk adsorption

4.2.4. Lead Removal by Orange peel Adsorbent

Water sample with Pb concentration 14.65 µg/L were taken to treat against Orange peels adsorption process. Intension of the treatment was bring down the concentration below its prescribed range and that was 10 µg/L. in step by step procedure 500 µm, 750 µm and 1000 µm sizes of orange peels with dose range from 1 g/L to 10 g/L were taken to get optimum value. For the experiments it was observed that orange peels works great to encounter Pb concentration from water sample. It was found to be 500 µm size of adsorbents works better than other two sizes because of more surface area to adsorb. At 4 g/L dose, 500 µm size of adsorbents can reduce the value below the standard concentration. The detailed result over this experiments clearly represented in figure 4.7.

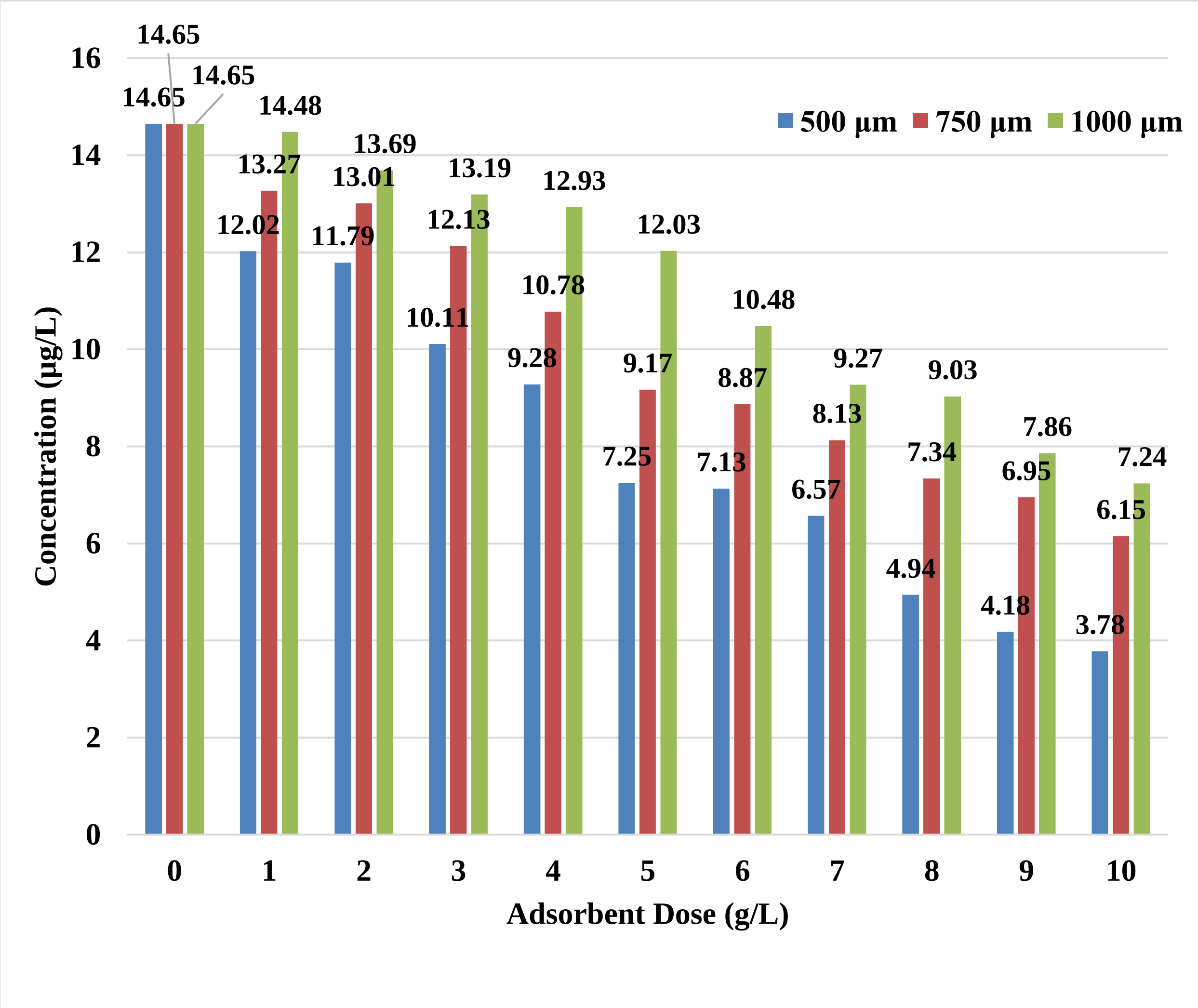

Figure 4.7. Lead Removal by Orange peel Adsorbent

4.2.5. Lead Removal by Sugarcane Adsorbent

Water sample with Pb concentration 14.65 µg/L were taken to treat against sugarcane husk adsorption process. Intension of the treatment was bring down the concentration below its prescribed range and that was 10 µg/L. in step by step procedure 500 µm, 750 µm and 1000 µm sizes of orange peels with dose range from 1 g/L to 10 g/L were taken to get optimum value. For the experiments it was observed that sugarcane husk works worst to encounter Pb concentration from water sample. It was found that none of the adsorbent sizes of adsorbents works perfectly to eliminate Pb. At 10 g/L dose, 500 µm size of adsorbents not able to reduce the value below the standard concentration. The detailed result over this experiments clearly represented in figure 4.8.

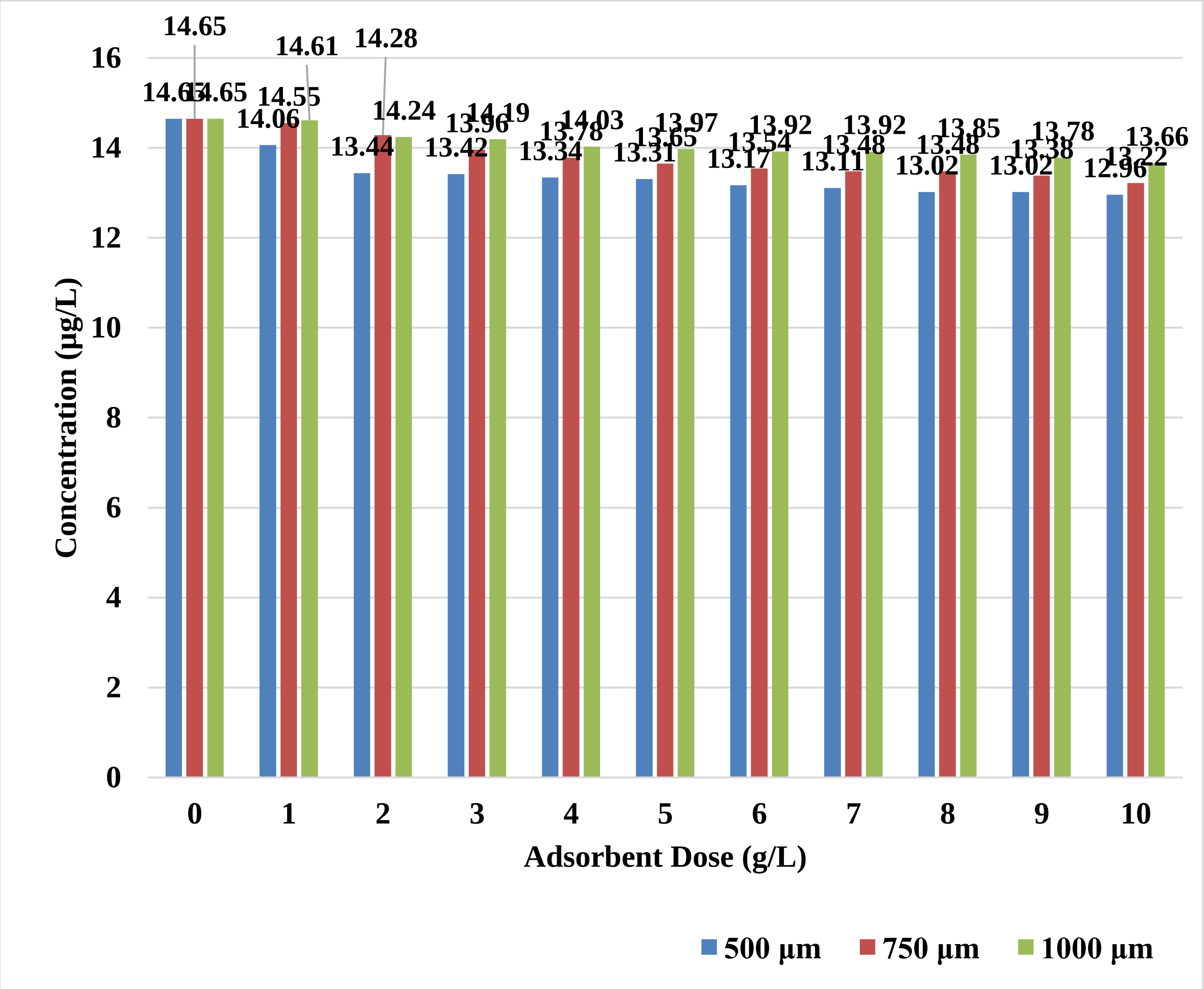

Figure 4.8. Lead Removal by Sugarcane Adsorbent

4.2.6. Lead Removal by Rice Husk Adsorbent

Water sample with Pb concentration 14.65 µg/L were taken to treat against rice husk adsorption process. Intension of the treatment was bring down the concentration below its prescribed range and that was 10 µg/L. in step by step procedure 500 µm, 750 µm and 1000 µm sizes of orange peels with dose range from 1 g/L to 10 g/L were taken to get optimum value. For the experiments it was observed that rice husk works better than other two to encounter Pb concentration from water sample. It was found to be 500 µm size of adsorbents works better than other two sizes because of more surface area to adsorb. At 3 g/L dose, 500 µm size of adsorbents can reduce the value below the standard concentration. The detailed result over this experiments clearly represented in figure 4.9.

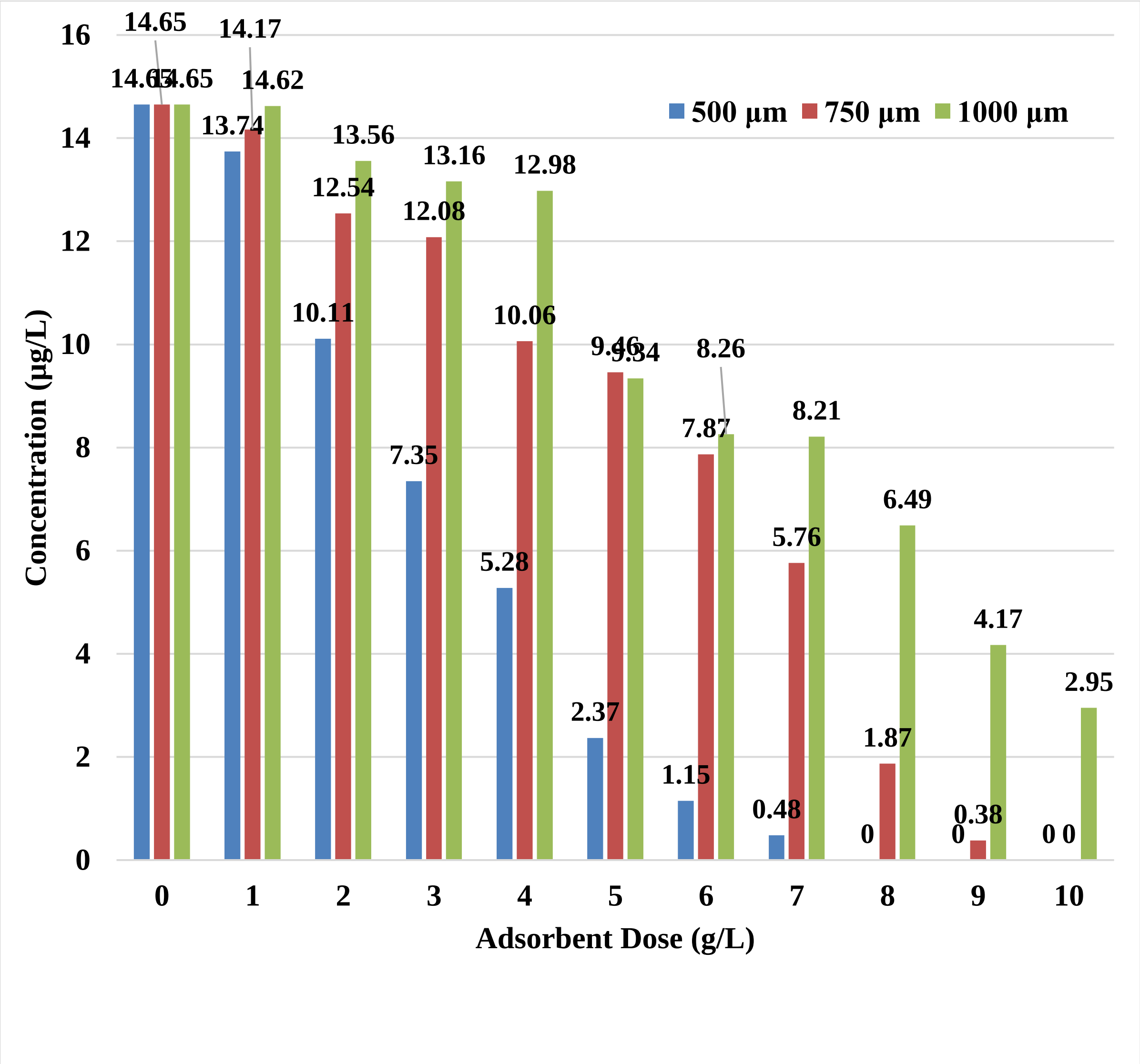

Figure 4.9. Lead Removal by Rice Husk Adsorbent

4.2.7. Removal of Fluoride by Orange peel adsorption

Water sample with F- concentration 1.75 mg/L were taken to treat against Orange peels adsorption process. Intension of the treatment was bring down the concentration below its prescribed range and that was 1 mg/L. in step by step procedure 500 µm, 750 µm and 1000 µm sizes of orange peels with dose range from 1 g/L to 10 g/L were taken to get optimum value. For the experiments it was observed that orange peels works not great to encounter F- concentration from water sample. It was found to be 500 µm size of adsorbents works better than other two sizes because of more surface area to adsorb. At 6 g/L dose, 500 µm size of adsorbents can reduce the value below the standard concentration. The detailed result over this experiments clearly represented in figure 4.10.

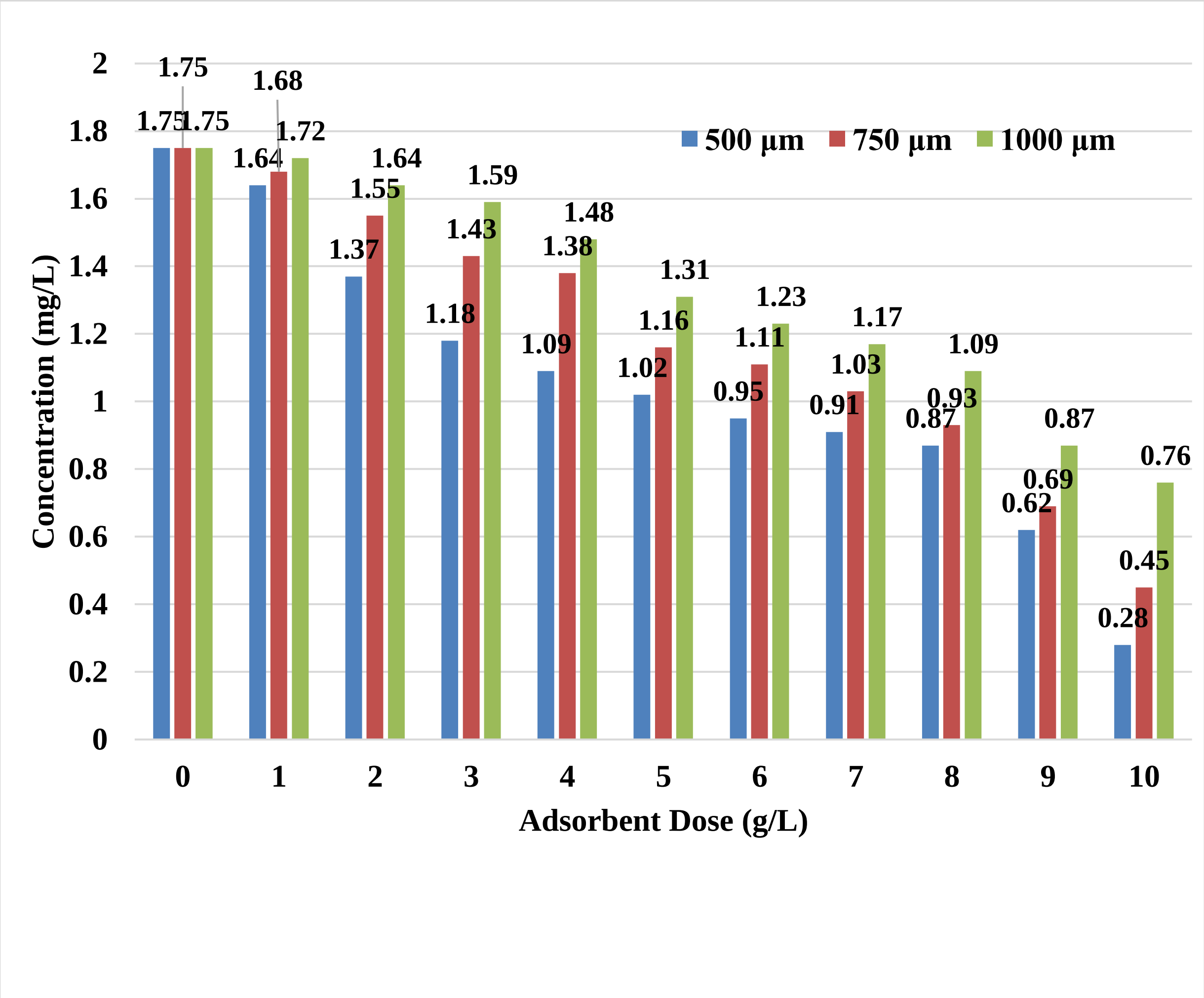

Figure 4.10. Removal of Fluoride by Orange peel adsorption

4.2.8. Removal of Fluoride by Sugarcane husk adsorption

Water sample with F- concentration 1.75 mg/L were taken to treat against sugarcane husk adsorption process. Intension of the treatment was bring down the concentration below its prescribed range and that was 1 mg/L. in step by step procedure 500 µm, 750 µm and 1000 µm sizes of orange peels with dose range from 1 g/L to 10 g/L were taken to get optimum value. For the experiments it was observed that sugarcane husk works best to encounter F- concentration from water sample. It was found to be 500 µm size of adsorbents works better than other two sizes because of more surface area to adsorb. At 2 g/L dose, 500 µm size of adsorbents can reduce the value below the standard concentration but for safer hand 3g/L were considered as optimum dose. The detailed result over this experiments clearly represented in figure 4.11.

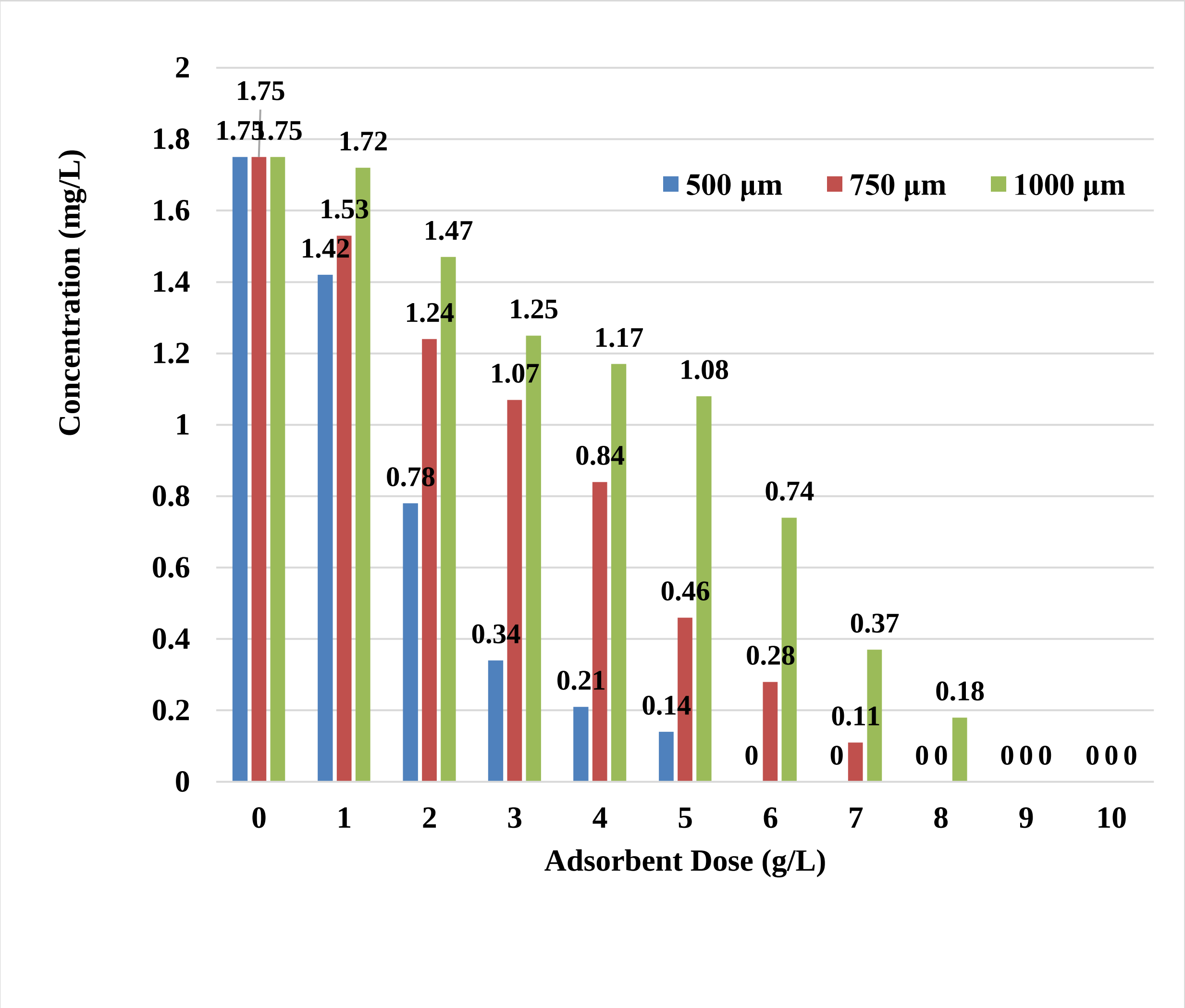

Figure 4.11. Removal of Fluoride by Sugarcane husk adsorption

4.2.9. Removal of Fluoride by Rice husk adsorption

Water sample with F- concentration 1.75 mg/L were taken to treat against rice husk adsorption process. Intension of the treatment was bring down the concentration below its prescribed range and that was 1 mg/L. in step by step procedure 500 µm, 750 µm and 1000 µm sizes of orange peels with dose range from 1 g/L to 10 g/L were taken to get optimum value. For the experiments it was observed that rice husk works worst to encounter F- concentration from water sample. It was found to be 500 µm size of adsorbents works better than other two sizes because of more surface area to adsorb. At 10 g/L dose, 500 µm size of adsorbents cannot able to reduce the value below the standard concentration. The detailed result over this experiments clearly represented in figure 4.12.

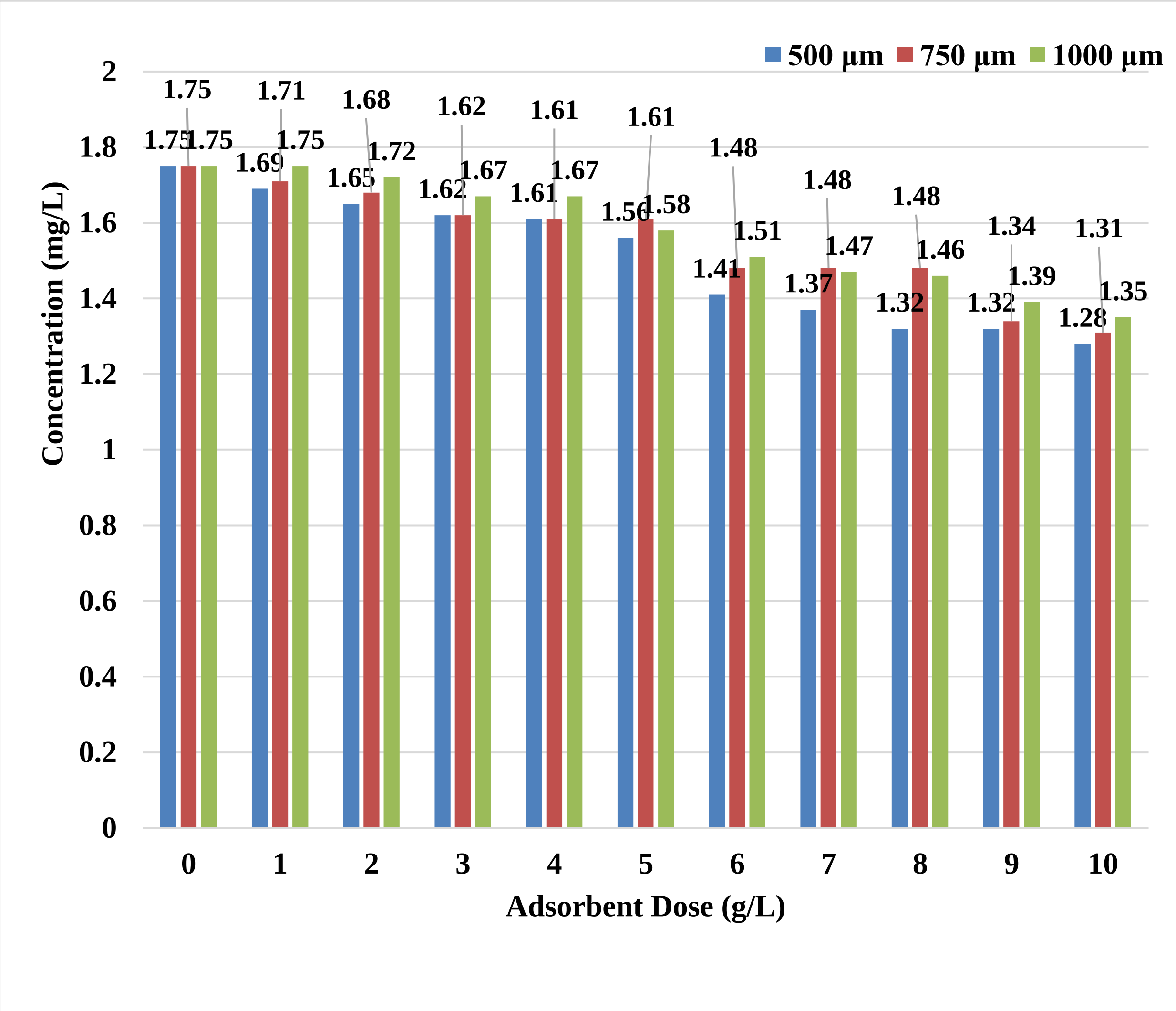

Figure 4.12. Removal of Fluoride by Rice husk adsorption

4.3. Result for design and performance evaluation of treatment unit

4.3.1. Calculation of Design specifications

4.3.1.1. Flow rate:

Flow rate inside the filtration unit were considered same as water filtration rate. Water filtration rate were again considered same as treatment unit available in market (ie. RO)

Q = 12 Lit/30 minutes = 6.67 ml/sec

4.3.1.2. Retention Time

Retention time for this case was combination of adsorption duration and setting duration. The retention time was optimized in the laboratory and compared the same with the values available in literature. The value of the retention time were finalized through below mention equation:

t = 1.5 minutes or 90 sec

4.3.1.3. Volume of imaginary pipe

The length of imaginary pipe was considered same as water travel length starting from inlet to outlet. The length is nothing but the product of flow rate and Retention time. The same equation was mathematically represented in below equation:

Q*t = 6.67 * 90 = 600.3 ml

4.3.1.4. Other Design consideration

Length of column = 3 * diameter of column

Diameter of connecting pipe = 1/6 * diameter of column

Let, diameter of pipe = d

So, diameter of column = 6d and length of column = 18 d

4.3.1.5. Water travel length

As, in the design of treatment unit 4 column of equal size considered and length of pipe connecting two adjacent columns are just half the column length, Total length travelled by water from inlet to outlet =

4 * 18d + 3 * 9d = 99d

4.3.1.6. Size of connecting pipe (d)

$\pi / 4d^2 * 99d = 600.3$ ml

so, d = 1.98 cm, say 2 cm

4.3.1.7. Diameter of each column (D):

$D = 6d = 6 * 2$

so, D = 12 cm

4.3.1.8. Length of each column (L):

$L = 3D = 3*12$

so, L = 36 cm

4.3.1.9. Height of pipe bend at each column (L):

$h = L/2 = 36/2$

so, h = 18 cm

4.3.2. Amount of adsorbent need to pack

4.3.2.1. Volume of each column

$\pi / 4D^2 * L = \pi / 4*12^2 * 36$

$= 4070$ cm^2 (approx.)

$= 0.004$ m^3 (approx.)

4.3.2.2. Amount of adsorbent (kg)

It was important to calculate amount of adsorbent required for each column to pack those perfectly. In table 4.5., details amount of various adsorbents along with density after packing has been mentioned. From the calculation it was found that designed Orange peels column, Rice husk column and sugarcane husk columns required 1.25 kg, 1.65 kg and 1.3 kg of adsorbents respectively. Density of all three column materials calculated as 312.5 kg/m^3, 412.5 kg/m^3 and 325 kg/m^3 respectively.

Table 4.5. Amount of adsorbents required to pack various designed column.

Adsorbent	Amount (Kg) – approx.	Density of packed material (kg/m^3) - approx.
Orange peel	1.25	312.5
Rice husk	1.65	412.5
Sugarcane husk	1.30	325

4.3.3. Column refill duration (column life)

4.3.3.1. Drinking water consumption per day per family

7 L/day/head * 5 person/family (average)

= 35 L/day (approx.)

4.3.3.2. Water treatment rate

Optimum dose for each adsorbent from result of objective 2 = 3 g/L

On an average ability of adsorbent media to treat 7 times

So, 3 g adsorbent can treat 7 L of water

Thus, 1 g adsorbent can treat 7/3 L of water

4.3.3.3. Column refill duration for various adsorbent

Amount of adsorbents requires to pack in each column, amount of water can be treated using those amount and column life in days are clearly represented in table 4.6. Where, designed Orange peels column, Rice husk column and sugarcane husk column can treat 2916 L, 3850 L and 3033 L of water respectively. Calculated column life were found to be 83 days, 110 days and 86 days respectively for all three column. On an average the treatment unit can be used for 3 month without replacement of packing adsorbents. From this result it was concluded that every three month column material replacement is required.

Table 4.6. Various column life (days)

Adsorbent	Amount packed in column (g) – approx.	Amount of water can treat (L) – approx.	Column life (days)
Orange peel	1250	2916	83
Rice husk	1650	3850	110
Sugarcane husk	1300	3033	86

4.3.4. Design and fabrication of Water filter based on adsorption study

Gradual deterioration of drinking water quality with time will be the greatest challenge in forthcoming future. Economically backward people would not be able to effort high cost and high maintenance drinking water filter. Available low budget filters are unable to make the water quality as prescribed by WHO.

With consideration of above mentioned problem, a new technology based, low budget, low maintenance, highly efficient drinking water filter (household) has been designed and proposed. Poor people can effort the newly designed filter, power consumption is 60% of existing system, water use rate is 100% (where 20% in existing system), Zero maintenance cost, component replacement cost is also nil.

The details specification and sequence of treatment process clearly described below figure 4.13.

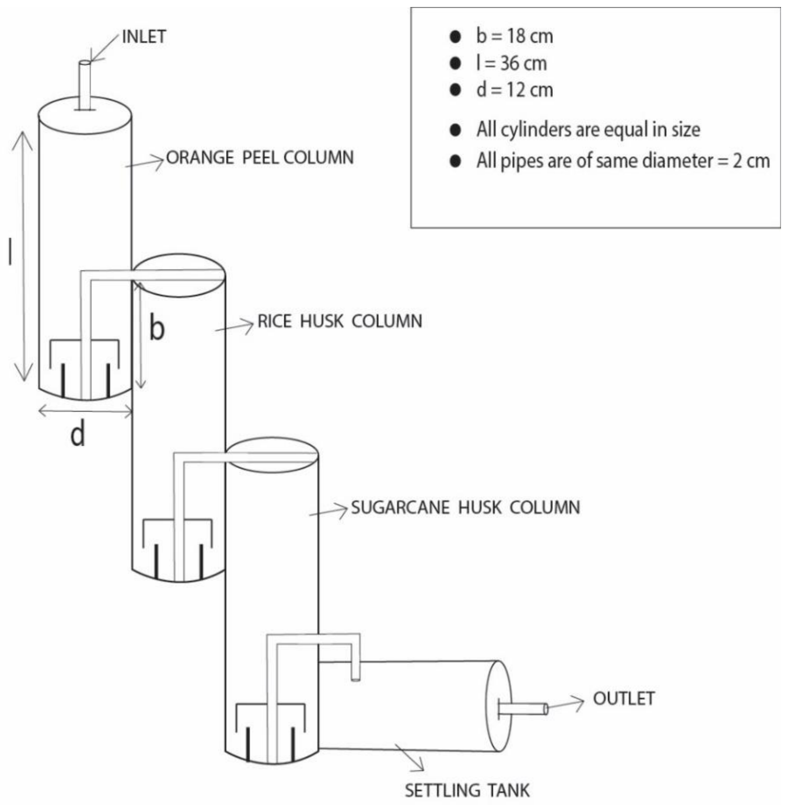

Figure 4.13. Schematic flow diagram of designed treatment unit

Three adsorbent packed column namely orange peel column, rice husk column and sugarcane husk column are connected in series. Outlet of one column ends as inlet of next column to enhance sequential treatment and removal of unwanted substances. Best and optimized size of adsorbents at all the columns are 500 μm. various adsorbents are having ability to remove various heavy metals (Pb and Cd) and ions (Fluoride). Length (36cm), diameter (12 cm) and bottom mechanism of every column has designed in such a way, it can enhance best adsorption time to remove substances and water can flow through gravitational force. The main function of bottom mechanism is to restrict water to carry adsorbent materials. At the end one 36 cm long settling tank has been provided to enhance the settlement of remaining adsorbent from treated drinking water.

To encounter high concentration heavy metals and ions from drinking water, freely available organic/bio adsorbent has been used. Three different organic adsorbent namely Orange peel, Rice husk and Sugarcane husk are placed and packed in series of well mechanized cylindrical column. Used adsorbents media can be replace with new one without any technical person and not require to buy any component.

The main technology in existing system is Reverse Osmosis that requires high cost and maintenance. Actual photograph of designed treatment unit as mentioned in below figure 4.14.

Figure 4.14. Actual photograph of designed treatment unit

4.3.5. Performance evaluation

To evaluate performance of designed treatment unit Gurgaon water were taken where all the parameters were pre analyzed. After sequential treatment of same water, the characteristics were re-analyzed and it was found that all the parameters are below prescribed range. The main parameters ie. F-, Cd and Pb were found to be Bellow Detection Level (BDL).

Table 4.7. Standards of various quality parameters and Characteristics of water pre as well as post treatment

	pH	Turbidity (NTU)	Total Alkalinity (mg CaCO3 /L)	Total Hardness (mg $CaCO_3$/L)	TDS (mg/L)	Chloride (mg/L)	Fluoride (mg/L)	Cadmium (µg/L)	Lead (µg/L)
Acceptable limit as per IS 10500 : 2012	**6.5-8.5**	**1**	**200**	**200**	**500**	**250**	**1**	**3**	**10**
Before Treatment	**7.6**	**0.5**	**598**	**578**	**135.2**	**52.5**	**1.75**	**5.25**	**14.65**
After Treatment	**7.3**	**0.4± 0.1**	**92.5 ± 7.5**	**135 ± 11**	**117 ± 12.5**	**16.5 ± 3.5**	**BDL**	**BDL**	**BDL**

4.4. Result for water wastage ratio and cost analysis

4.4.1. Estimation of water wastage ratio

In section 4.4.1.1 and 4.4.1.2 water wastage ratio of designed treatment unit and RO unit were calculated using conventional mathematical formulae. Ratio of amount of water wastage at each unit and amount of water drinkable were considered.

4.4.1.1. Water wastage ratio for designed treatment unit

Water wastage ratio = Amount of water wastage/Amount of water drinkable

= (Input – Output)/ Output

= (1L -1L)/1L = 0

The calculated value represents there is no generation of wastewater.

4.4.1.2. Water wastage ratio of RO unit

Water wastage ratio = Amount of water wastage/Amount of water drinkable

= (4.15L/1L)

= 4.15:1

The result represents approx. 4 times of drinkable water continuously wastes at RO unit.

4.4.2. Cost estimation

Cost estimation is one of the important step for proposing any new techniques for check financial feasibility. Sections 4.4.2.1 and 4.4.2.2., represents cost estimation for raw materials and other costs respectively.

4.4.2.1. Cost of Raw materials

Various raw materials of different specifications requires for design of filtration units. Initially calculated the cost for individual component then converted to INR and finally added all the values to get final result. Cost for various components like PVC 5 inch diameter pipe, PVC 5 inch diameter cap, PVC 4 inch diameter pipe, PVC 3 inch diameter pipe, PVC solvent and PVC 2 cm diameter are INR 128.25, 148, 12.1, 9.7, 25 and 33 respectively. A total cost for raw materials were calculated and rounded as INR 360/. The details specifications and values mentioned in table 4.8.

Table 4.8. Estimated cost requires for Filter making

Headings	Price in USD (As per www.alibaba.com - dated 24 Aug 2020)	Price in INR (Dated 13 September 2020, 1USD = 73.48 INR)	Required raw material for each filter	Actual amount (INR)
PVC pipe 5 inch dia	1.16 USD/m	85.50 INR/m	1.5 m	128.25

PVC cap for 5 inch dia	0.25 USD/pc	18.50 INR/Pc	8 pc	148
PVC pipe 4 inch dia	0.82 USD/m	60.50 INR/m	0.2 m	12.1
PVC pipe 3 inch dia	0.66 USD/m	48.50 INR/m	0.2 m	9.7
PVC solvent	1.7 USD/kg	125 INR/Kg	200 g	25
PVC pipe 2 cm dia	0.3 USD/m	22 USD/m	1.5 m	33
				356.05 say, **Rs. 360/**

4.4.2.2. Estimation of Other costs

Other costs for this study were includes Cost of fabrication, Cost of Adsorbent, Cost for electricity and Cost of maintenance and calculated values were INR 250, 175, 0 and 350 respectively. The details costing and their values mentioned in table 4.9.

Table 4.9. Estimated other costs

	Details	**Amount (INR)**
Cost of fabrication	Wage of fabricator = INR 800/day, Time required for manual febrication = 2.5 hours (approx)	250
Cost of Adsorbent	Raw material (Free of cost)	0
	Adsorbent preparation cost (Half man-day with labour rate) - wage of labour = INR 350	175

Cost for electricity	Free (as driving force of the filter is Gravitational force, no electricity required)	0
Cost of maintenance	One man-day (Average) for one time maintenance, based on wage of labor	350

Chapter 5

Conclusions

- Water quality of various locations of Haryana were studied and analyzed through literature and followed by laboratory test over same parameters. In both of the cases it was found that some of the heavy metals and ions are major problem in ground water of Haryana. The presence of industries, agricultural practices and other natural events may leads the ground water through those pollutants.
- A total of 8 location in random 8 districts of Haryana were considered and analyzed. Out of all the locations, Gurgaon water quality were found to be worst. Values of Fluoride (mg/L), Cadmium (µg/L), and Lead (µg/L) were found to be 1.75, 5.25 and 14.65 respectively. The standard values of these parameters are 1 mg/L, 3 µg/L and 10 µg/L respectively.
- Health related issues due to bad quality of drinking water were studied and analyzed through research papers and followed by actual field survey. Main health related problem were found to be Kidney Damage, Damage to the brain, nervous system issue, red blood cells related issue, Muscle disorders, Thyroid disease, Arthritis, Dementia, Bone fractures, Bone cancer, Genetic damage, Increased tumor and cancer rate, Damaged sperm and increased infertility, Cardiovascular disease, Growth retardation, and Reproductive failure.
- A total of 65 family were surveyed which includes total of 289 family members of various age groups and collected data were analyzed. From the analyzed data it was found that mostly Kidney related and muscle related disease are being faced by local people.
- Water sample of Gurgaon were considered as inlet water to treat using various bio adsorbents to optimize the doses and finally utilize the same in designed water treatment unit. Orange peels, sugarcane husk and rice husk of size range 500 µm, 750 µm and 1000 µm were used with dose range from 1 g/L to 10 g/L

- Best bio adsorbent for removal of Cd, Pb and F- were found Orange peels of size 500 µm, rice husk of size 500 µm and sugarcane husk of size 500 µm respectively. Best combination of adsorbents can bring down the level of Cd, Pb and F- as 2.47 µg/L, 7.35 µg/L and 0.34 mg/L respectively. Optimum dose for all three cases were found to be 3 g/L.
- Three adsorbent packed column namely orange peel column, rice husk column and sugarcane husk column are connected in series. Outlet of one column ends as inlet of next column to enhance sequential treatment and removal of unwanted substances. Best and optimized size of adsorbents at all the columns are 500 µm.
- Various adsorbents are having ability to remove various heavy metals (Pb and Cd) and ions (Fluoride). Length (36cm), diameter (12 cm) and bottom mechanism of every column has designed in such a way, it can enhance best adsorption time to remove substances and water can flow through gravitational force.
- The main function of bottom mechanism is to restrict water to carry adsorbent materials. At the end one 36 cm long settling tank has been provided to enhance the settlement of remaining adsorbent from treated drinking water.
- Cost for various components like PVC 5 inch diameter pipe, PVC 5 inch diameter cap, PVC 4 inch diameter pipe, PVC 3 inch diameter pipe, PVC solvent and PVC 2 cm diameter are INR 128.25, 148, 12.1, 9.7, 25 and 33 respectively. A total cost for raw materials were calculated and rounded as INR 360/.
- Other costs for this study were includes Cost of fabrication, Cost of Adsorbent, Cost for electricity and Cost of maintenance and calculated values were INR 250, 175, 0 and 350 respectively.

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Annexure A

Analysis of health related issues

		Water related dieses known	Water related dieses unknown
Kidney Damage (kedney related issue)	53	46	7
Damage to the brain (Brain related issue)	4	0	4
Damage to the nervous system (nurves system related issue)	5	0	5
Anemia (RBC related issue)	14	3	11
Muscle Disorder (muscle pain etc.)	28	2	26
Thyroid disease (TSH related issue)	13	2	11
Infertility	0	0	0
Cancer	2	0	2
		53	66

Annexure B

Removal of Cd using orange peels

Adsorbent dose (mg/L)	500 µm	750 µm	1000 µm
0	5.25	5.25	5.25
1	4.18	4.12	4.78
2	2.97	3.24	4.17
3	**2.47**	**3.02**	**3.89**
4	2.17	2.76	3.38
5	1.05	1.62	3.12
6	0.57	1.13	2.87
7	BDL	0.73	1.22
8	BDL	0.51	0.98
9	BDL	BDL	0.66
10	BDL	BDL	BDL

Annexure C

Removal of Cd using Sugarcane husk

Adsorbent dose (mg/L)	500 µm	750 µm	1000 µm
0	5.25	5.25	5.25
1	5.12	5.13	5.13
2	4.09	4.22	4.94
3	**4.01**	**4.17**	**4.37**
4	3.75	3.98	4.36
5	3.36	3.73	4.31
6	3.13	3.44	4.19
7	2.77	3.09	3.77
8	2.72	2.81	3.21
9	2.58	2.81	2.65
10	2.21	2.59	2.55

Annexure D

Removal of Cd using Rice husk

Adsorbent dose (mg/L)	**500 µm**	**750 µm**	**1000 µm**
0	5.25	5.25	5.25
1	5.03	5.19	5.22
2	4.11	4.75	5.04
3	**3.76**	**4.29**	**4.59**
4	2.43	3.55	4.17
5	2.37	2.96	3.32
6	1.93	2.49	2.87
7	1.11	1.87	2.65
8	0.78	0.85	2.16
9	0.65	0.52	1.27
10	BDL	BDL	0.78

Annexure E

Removal of Pb using orange peels

Adsorbent dose (mg/L)	500 µm	750 µm	1000 µm
0	14.65	14.65	14.65
1	12.02	13.27	14.48
2	11.79	13.01	13.69
3	10.11	12.13	13.19
4	9.28	10.78	12.93
5	7.25	9.17	12.03
6	7.13	8.87	10.48
7	6.57	8.13	9.27
8	4.94	7.34	9.03
9	4.18	6.95	7.86
10	3.78	6.15	7.24

Annexure F

Removal of Pb using Sugarcane husk

Adsorbent dose (mg/L)	500 µm	750 µm	1000 µm
0	14.65	14.65	14.65
1	14.06	14.55	14.61
2	13.44	14.28	14.24
3	13.42	13.96	14.19
4	13.34	13.78	14.03
5	13.31	13.65	13.97
6	13.17	13.54	13.92
7	13.11	13.48	13.92
8	13.02	13.48	13.85
9	13.02	13.38	13.78
10	12.96	13.22	13.66

Annexure G

Removal of Pb using Rice husk

Adsorbent dose (mg/L)	500 µm	750 µm	1000 µm
0	14.65	14.65	14.65
1	13.74	14.17	14.62
2	10.11	12.54	13.56
3	7.35	12.08	13.16
4	5.28	10.06	12.98
5	2.37	9.46	9.34
6	1.15	7.87	8.26
7	0.48	5.76	8.21
8	BDL	1.87	6.49
9	BDL	0.38	4.17
10	BDL	BDL	2.95

Annexure H

Removal of F- using orange peels

Adsorbent dose (mg/L)	500 µm	750 µm	1000 µm
0	1.75	1.75	1.75
1	1.64	1.68	1.72
2	1.37	1.55	1.64
3	1.18	1.43	1.59
4	1.09	1.38	1.48
5	1.02	1.16	1.31
6	0.95	1.11	1.23
7	0.91	1.03	1.17
8	0.87	0.93	1.09
9	0.62	0.69	0.87
10	0.28	0.45	0.76

Annexure I

Removal of F- using Sugarcane husk

Adsorbent dose (mg/L)	500 µm	750 µm	1000 µm
0	1.75	1.75	1.75
1	1.42	1.53	1.72
2	0.78	1.24	1.47
3	0.34	1.07	1.25
4	0.21	0.84	1.17
5	0.14	0.46	1.08
6	BDL	0.28	0.74
7	BDL	0.11	0.37
8	BDL	BDL	0.18
9	BDL	BDL	BDL
10	BDL	BDL	BDL

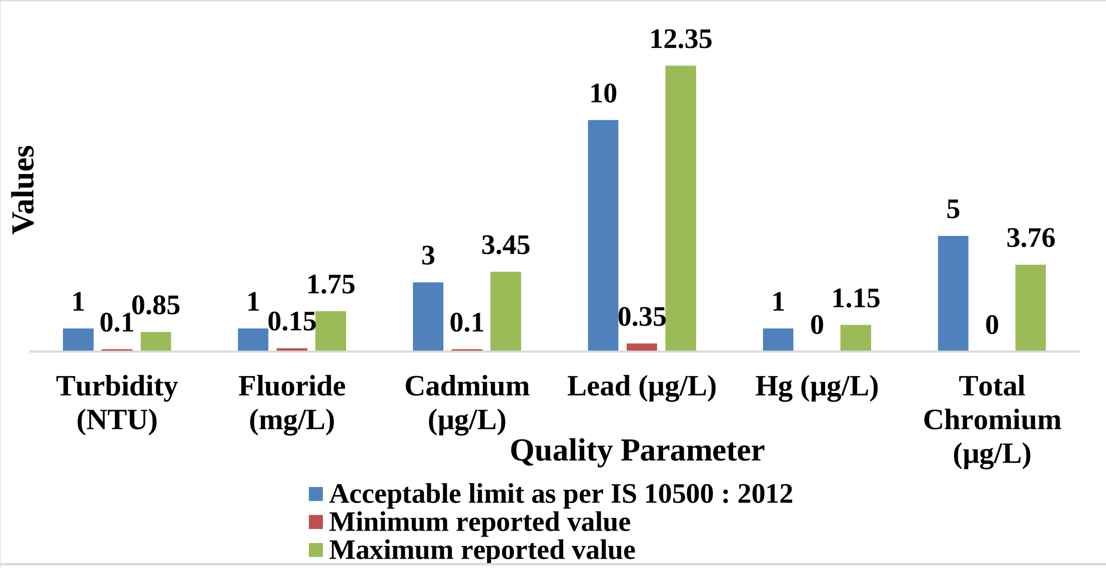
Annexure J

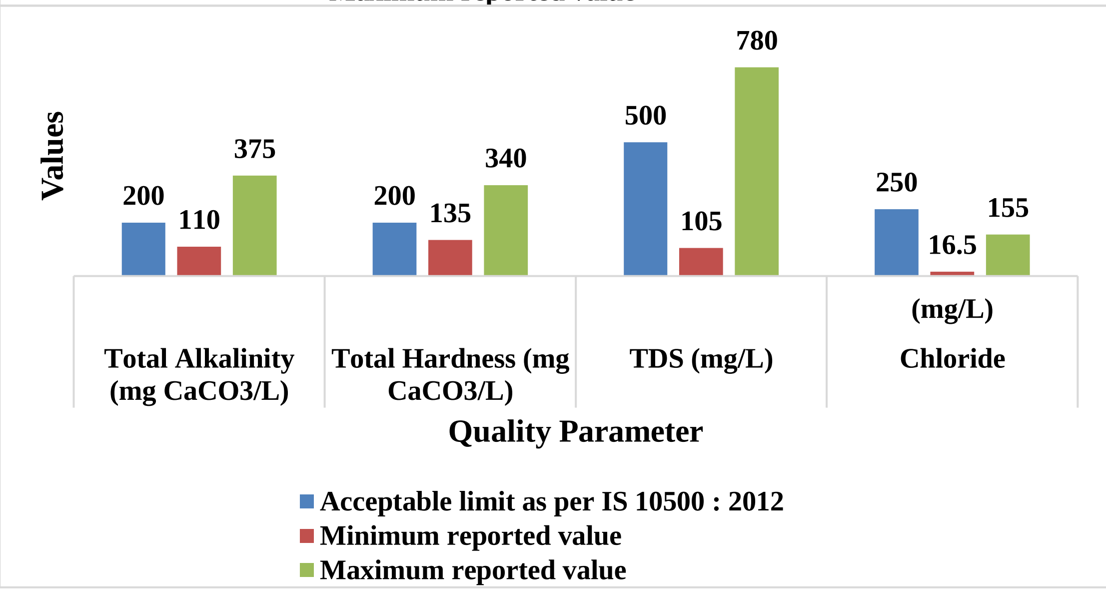
Removal of F- using Rice husk

Adsorbent dose (mg/L)	500 µm	750 µm	1000 µm
0	1.75	1.75	1.75
1	1.69	1.71	1.75
2	1.65	1.68	1.72
3	1.62	1.62	1.67
4	1.61	1.61	1.67
5	1.56	1.61	1.58
6	1.41	1.48	1.51
7	1.37	1.48	1.47
8	1.32	1.48	1.46
9	1.32	1.34	1.39
10	1.28	1.31	1.35

Annexure K

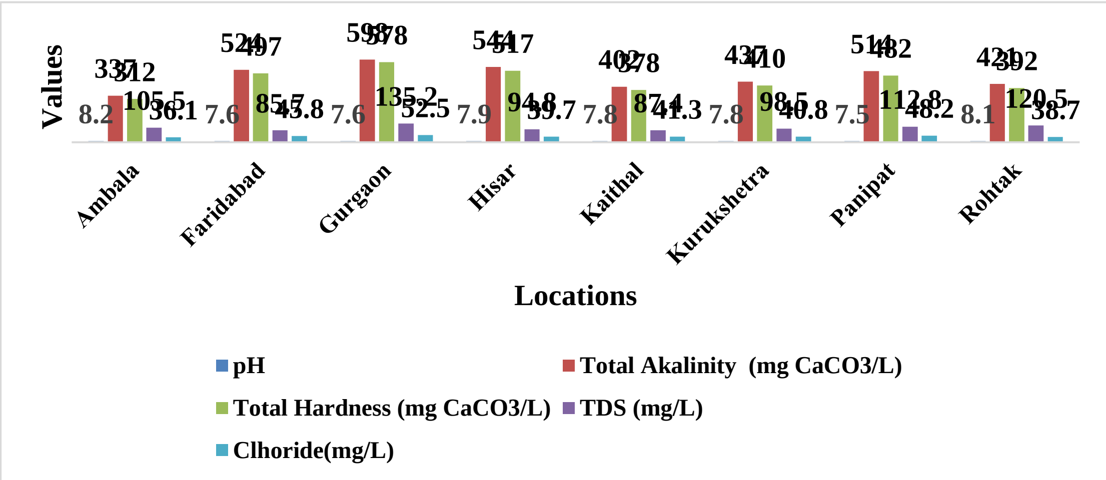
Ground water quality based on Literature survey

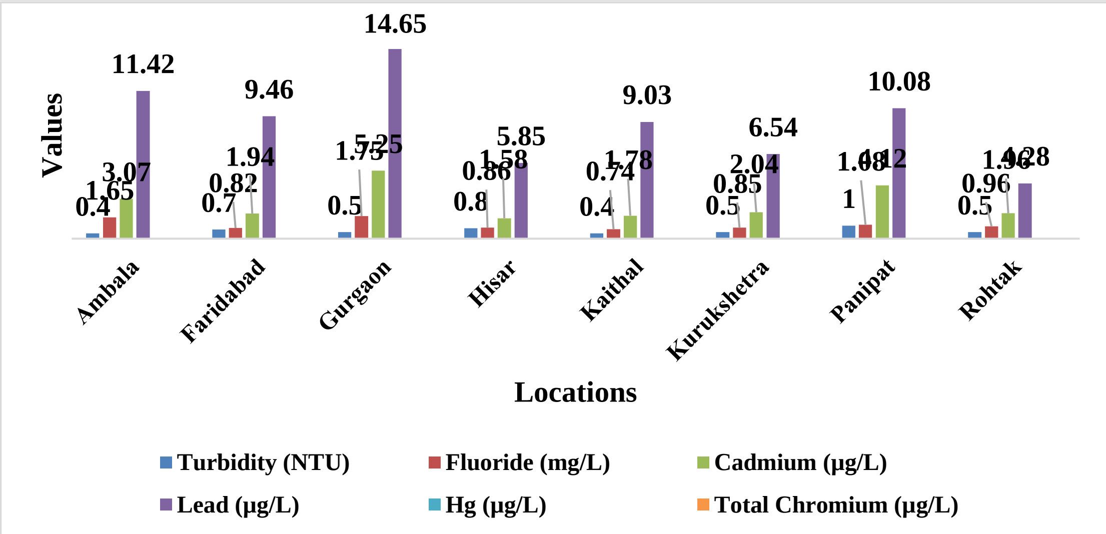




Annexure L

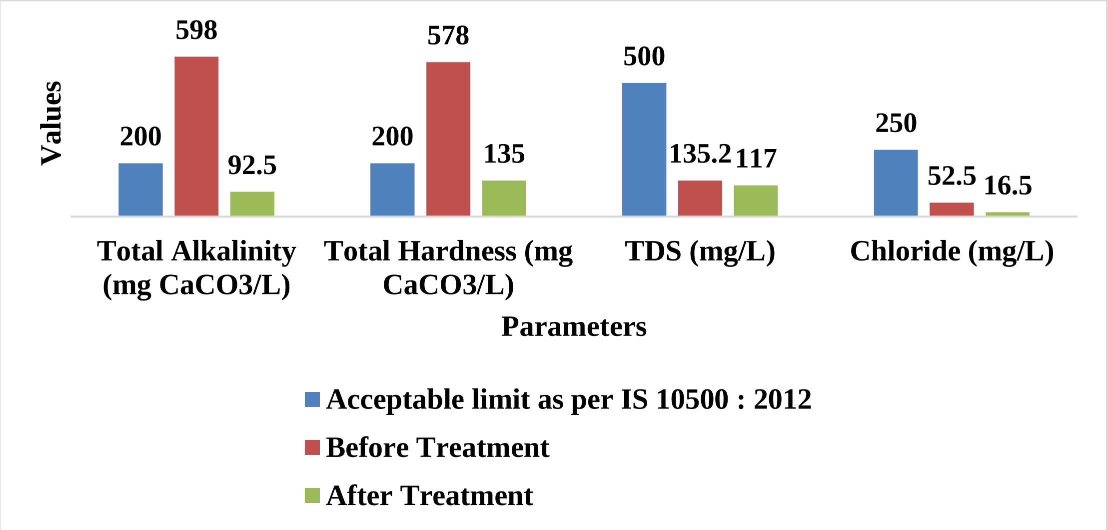
Ground water quality based on Laboratory analysis

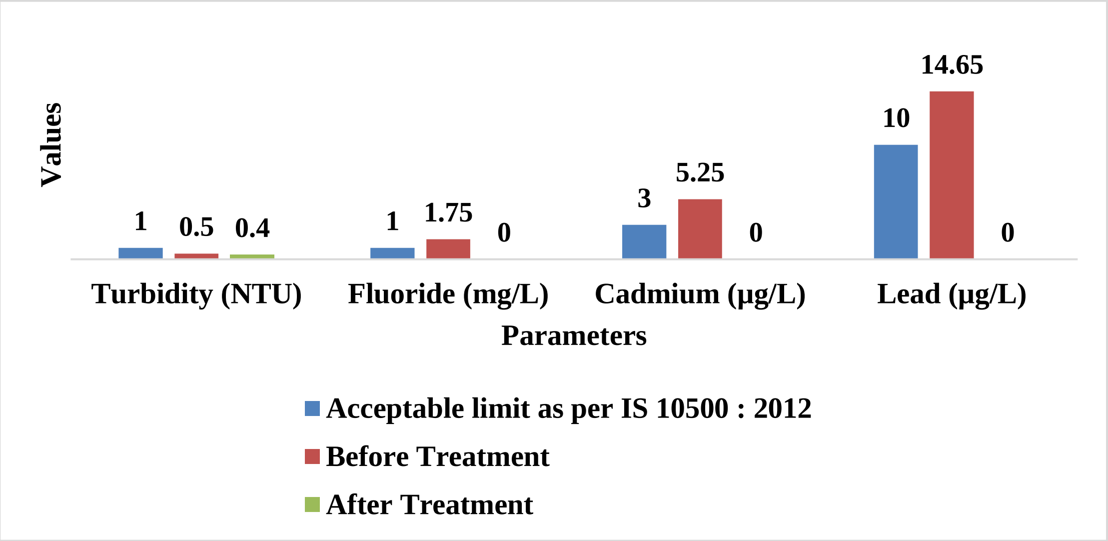




Annexure M

Performance evaluation of designed water treatment unit





Annexure N

Plagiarism Proof

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SA	**1324769190-TS.pdf** Document 1324769190-TS.pdf (D42306895)	3
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Annexure O

Publications

1. Removal of Lead from Drinking Water by Bio-adsorption Technique: An Eco-friendly Approach, Nature Environment and Pollution Technology An International Quarterly Scientific Journal, Prasenjit Mondal†, B. P. Yadav and N. A. Siddiqui, University of Petroleum and Energy Studies, Dehradun, U.K., India

2. Fluoride removal from water using ceramic based adsorbent prepared from spent mosquito repellent liquid vaporiser rods, International Journal of Environmental Analytical Chemistry, Sarthak Suhane, Rishabh Rastogi, Sachin Dhakad, Aniket Kinkar, Prasenjit Mondal, B. P. Yadav & Abhishek Nandan

3.A WATER FILTRATION SYSTEM, Application No.202011031120 A, Publication Date : 18/09/2020.