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Physicochemical and pathological assessment of groundwater quality from Sargodha, Pakistan using hybrid multi-layer slow sand filter: pre and post treatment analysis

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ABSTRACT

One of the main issues confronting humanity in the twenty-first century is the lack of potable water availability. Around half of the world's consumers face drinking water scarcity. Industrially rich areas have a high population and high-water contamination risk factors. Modern technologies that are quite effective for water purification, present economical limitations that impede their usefulness in developing countries. Conventional methods involving low energy, low chemical demand, and prevention of water-borne disease are therefore significant for water purification in developing countries like Pakistan. These limitations have led to improvising the conventional method for facile water purification. Herein we report the water purification assembly based on allow sand filtration; involving the raw materials grass, clay, sand, silt, pebbles, gravel and coal/ fly ash carbon to obtain clean and quality-controlled water treatment. Ground water samples collected from various areas of Sargodha city were subjected to the developed design Hybrid Multi-Layer Slow Sand Filter (HMLSSF). Based on pre- and post-treatment water analysis, it was determined that the filtration assembly was quite effective at reducing pH, turbidity, dissolved and suspended solids, hardness, and heavy metals percent removal by 87%, 77.7%, 91.3%, 95.4%, 84.4%, and to promising levels, respectively. Moreover, 99 % biological contamination such as total coliform was also removed by this method.

1. Introduction

Water is a fundamental resource, integral to all ecological and societal activities, including food and energy production, transportation, waste disposal, industrial development, and human health. Clean water scarcity is a significant problem in today's world, where the world population rises to 7.7-billion-person. At present, 47% world's population faces water scarcity one month each year The strain on water resources will further until 2050 when the world population will have grown by 22 to 34% to 9.4 to 10.2 billion people, and the strain on the water system will be greater [1]. The standard for freshwater consumption per person worldwide is 1000 m^3 per year; by 2025, various studies predict that this amount will drop to between 600 and 800 m^3. The requirements for food may be met by the treated industrial wastewater [2].

Water is an important need for living organisms to ensure metabolic processes. Water treatment is necessary once drinking water has been contaminated. The water may be accepted for drinking purpose if it is free from colour/tint, smell, suspended matter and bacteria and under the safe mineral limits of drinking water guidelines and posing no hazard to the consumers. Agricultural, industrial, and animal farming discharge all have the potential to contaminate water supplies [3]. Water contaminants are mostly dissolved metals, organic matter, inorganic non-metallic matter, and microbial contamination. Metals are hard, opaque, and conductive materials. "Heavy metals" are regarded as the elements having specific gravity between 4-5 and are classified as "toxic contaminants". Heavy metals include, chromium (Cr), nickel (Ni), copper (Cu), zinc (Zn), lead (Pb), and arsenic (As). These heavy metals once enter into the body, cannot be excreted from body and start accumulating in body. Longer contact to these metals may lead to health issues such as, kidney failure (Cd) [4], reproductive health problems (Pb) [5], edema, respiratory issues, liver, kidney and heart failure (Co) [6], lung cancers, skin melanoma (As) [7], hyperpigmentation, and neurological damage (Hg) [8]. Organic matter in water can be present in the particulate form or in dissolved form and is designated as "particulate organic matter" (POM) and "dissolved organic matter" (DOC). Organic matter is not harmful to the human health until water is treated with chlorine during disinfection process which lead to the formation of trihalomethanes (THMs) and haloacetic acids (HAA). Organic matter can be hydrophilic or hydrophobic. Inorganic matter includes the contaminants consisting of compounds with no carbon or carbon is bonded to elements other than hydrogen. These include nitrogen, sulphur, chlorine, and phosphorus containing contaminants. Nitrogen exposure to infants leads to blue-baby syndrome, whereas sulphate causes diarrhea and bitter taste. Natural chloride is present in most of the water resources due to leaching of rocks and soils that contain chloride. Diarrheal disorders are brought on by microbial pathogen contamination of drinking water. Total coliform (Fecal coliform and Escherichia coli), Legionella, Giardia lamblia, Cryptosporidium, and viruses are all examples of microbial contamination. USEPA has mandated that less than 5% of the samples must have total coliform in drinking.

The most common method for water treatment is filtration. Filtration can be facilitated by sand [9], activated charcoal [10], membrane bioreactors [11], nanoparticles [12], nanoparticle-based membranes, polymeric nanocomposites [13, 14]. Water treatment techniques can be aeration, coagulation, osmosis, desalination, distillation, and ion exchange. Sand filtration plants are the conventional and economical method for water purification in developed and underdeveloped countries. Sand filters operate by physically removing the suspended particles or debris from the water samples [15]. Furthermore, sand filters have been reported for removal of heavy metals [16, 17], pesticides, and biological contaminants [18, 19].

Sargodha is among the largest cities of Pakistan. The groundwater of the city has been overexploited due to the recent rising trend in urban population and the ongoing urbanization. The ground water quality has been characterized as poor in various aquifers around of Punjab Plain and Sargodha having different depths. The same water quality is posing substantial health hazards to the local consumers and affecting the ecosystem, livestock, and crops adversely [20].

In this study, we report the development of an economical method for the purification of drinking water by modifying the sand filtration method. We intended to improve the quality of drinking water (for the physical parameter, chemical, and biological) for drinking purposes through low-cost local materials.

2. Materials and Methods

2.1. Materials

The main materials used in this treatment plant were clay, grass, sand, pebbles, gravels, coal, muslin clothe and bucket tap. Clay was procured from local potters' market in Islamabad city while sand, silt, pebbles were brought from near Indus River. The ceramic pot, bucket, coal and muslin cloth were bought from local market of Islamabad.

2.2. Sample Collection

Groundwater samples were obtained from various locations of Sargodha in clean glass bottles (1 Liter). These samples were analyzed in the Laboratories of PCSIR, Islamabad. Table 1.

Table 1

Sampling Location of Sargodha

Sr No.	Sample Codes	Location
1	S1	New Satellite Town
2	S2	Ali Town
3	S3	Jamia Masjid Bilal Bypass Faisalabad Road
4	S4	Shell Petrol Pump Bypass Faisalabad Road
5	S5	Chak # 50
6	S6	Chak # 47
7	S7	Government Istitue of Commerce for Women Chak # 47
8	S8	Murad Colony
9	S9	Farooq Colony
10	S10	University Road, Kilyari Town
11	S11	Jafria Colony Chowk
12	S12	Usmania Colony, Old Civil Line
13	S13	Essa Nagar
14	S14	Civil Hospital, Sargodha
15	S15	Bhatti Chowk

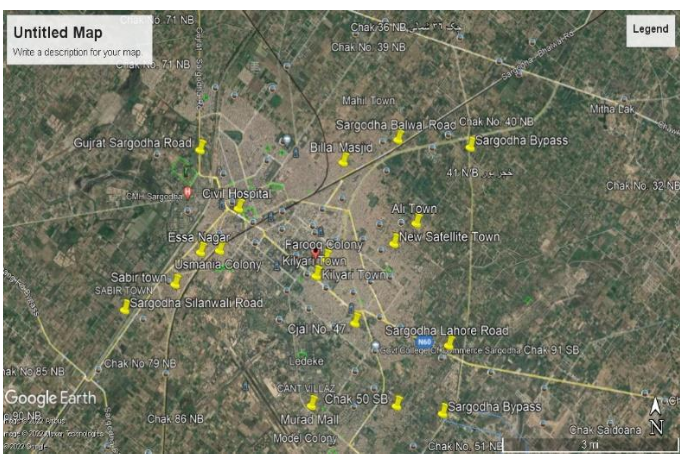

Fig. 1. Location Map of Samples Collected from Sargodha City

2.3. Working Methodology

2.3.1. Methods for physical properties

Physical methods such as pH, conductivity, and turbidity were calculated at the time of collection by using digital pH meter (Hanna Instruments pH 210), conductivity meter (Hanna Instruments HI 9932), and turbidity meter (Hanna Instruments HI 9932) respectively. The color, smell and taste were observed esthetically by six analysts.

2.3.2. Methods for chemical properties

For total solid, total dissolved solid and total suspended solid following gravimetric calculations were carried out after recommended filtration. Total hardness of the water was calculated by using the volumetric titration method leading to Calcium (Ca) and Magnesium (Mg) present in the water samples. Chlorides were determined volumetrically through Argentometric titrations. Sulfates were precipitated as barium sulfate and determined gravimetrically. Total alkalinity was estimated by titration against standard acid.

Trace metals analysis was carried out by using ICP-MS (Agilent inductively coupled plasma mass Spectrometer 7800ICP-MS with HMI) for Al, Cr, As, Mn, Fe, Co, Ni, Cu, Zn, Se, Cd, and Pb were analyzed.

2.3.3. Methods for pathological detection

E. *coli*, Thermo tolerant coliform, and total coliform bacteria were evaluated by using standard methods. Briefly, media was poured in clean petri dishes, 100 mL of the drinking water was separated through a membrane filter by using vacuum filtration assembly. Membrane filters were placed in clean petri dishes and petri dishes were incubated at 35 °C for 24 hours. After 24 hrs, visible colonies of coliform bacteria turned pink or dark red with a lustrous shine. Triplicate samples were used for each sample.

Coliforms/100mL = (Number of colonies counted) ×100/ Sample size, Ml

2.3.4. Fabrication process of the water treatment plant

The process was designed and fabricated using locally available materials that are relatively cheap and readily available from the indigenous resources. The filtration assembly is based on clay, sand, silt, pebbles grog, coal/fly ash carbon. The flow sheet of the assembly is illustrated from Fig. 2.

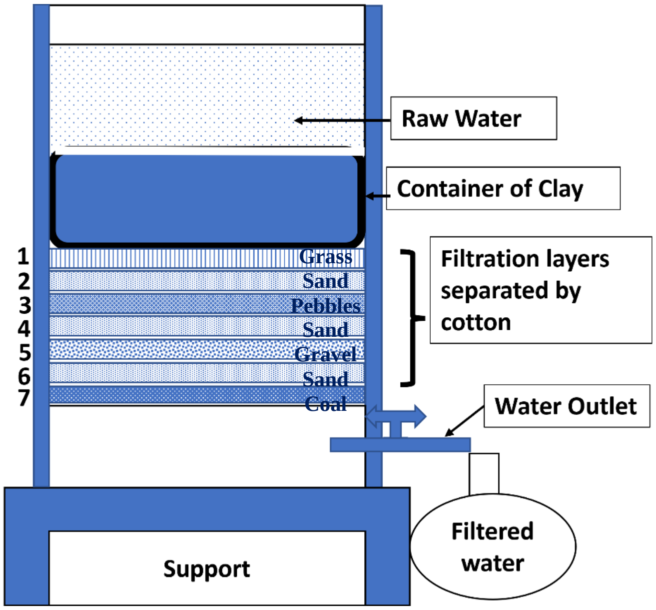

Fig. 2. HMLSS Filtration Assembly for water purification including seven layers of thickness separated by a thin layer of cotton.

The assembly of HMLSSF was consisted of two buckets of 19 Liters capacity. One bucket is served as a storage to feed the filter and placed top on the other bucket while the bucket at the downside is served as the actual filter. The sand used as filter medium was sieved through 0.20 mm, 0.4 mm and gravel sieved through 5 mm. The sand was purified by keeping in water for 48 hours, thoroughly washed to remove organic matter and other interfering impurities and dried under sun for additional 48hrs. Washing of sand filter material is necessary to have a clean filter bed that free from some soluble minerals. All materials were placed in the form of beds of 1.0 cms in the bucket. All the layers with separated by Cotton cloth. The capability of produce water after treatment was checked against WHO drinking water standards.

3. Results and Discussion

3.1. Performance Evaluation of The Fabricated Filter and Water Quality Analysis

The filtration capacity of the HMLSSF was determined by adjusting flow rate of water through the slow sand filtration in order to produce clean filtered water in liter per hour. The control tap of the storage tank was opened and the raw water flow from the tank into the filter chamber where the water was filtered by the beds of all materials. A stopwatch was switched on immediately when water reaches the filter chamber and switched off when the cylinder was filled to 1 liter level. The flow rate was determined using following Eq. 1.

$$Q = V/T \tag{1}$$

$$Q = 1/211 \times 60 \times 60$$

$$Q = 0.01706\ m^3/h$$

The average time taken by the water through the filter to fill 1 liter for five repetitions and found to be 211 s. Clean and sterilized plastic bottles were used to collect water samples for the analysis. The physical, chemical, and bacteriological properties of the water were determined using the standard method given by standard method for the examination of water and wastewater (2017) and compared with the WHO drinking water standards.

This multilayer slow sand filter has a capacity to produce 17.06 liters/h of clean water that is safe for consumption.

3.2. Real Sample Application Study On Sargodha City Ground Water

In order to investigate the aims addressed above, the efficacy of the proposed filtration system was assessed experimentally by evaluating the factors that influence performance of filter using real sample study. The ground waters collected from all 15 (fifteen) locations of Sargodha city were treated through the fabricated filtration process system and evaluated on the basis of physical, chemical, and bacteriological properties and compared with the non-filtered (raw) water. The filter was brought its maturity by 10 L water samples from ground water source. The Filter took one week to mature.

3.3. Post Treatment Evaluation of Physical Characteristics of Filtered Water

According to WHO standards drinking water the permissible limit of pH is 6.5 to 8.0 [21]. pH below or above these may lead to gastrointestinal problems. pH of water samples in Sargodha was found in safe limits. Post Treatment of water samples showed that pH was lowered by the difference of 0.4 to 0.6. Trend in the pH of the samples is shown in Fig. 3a.

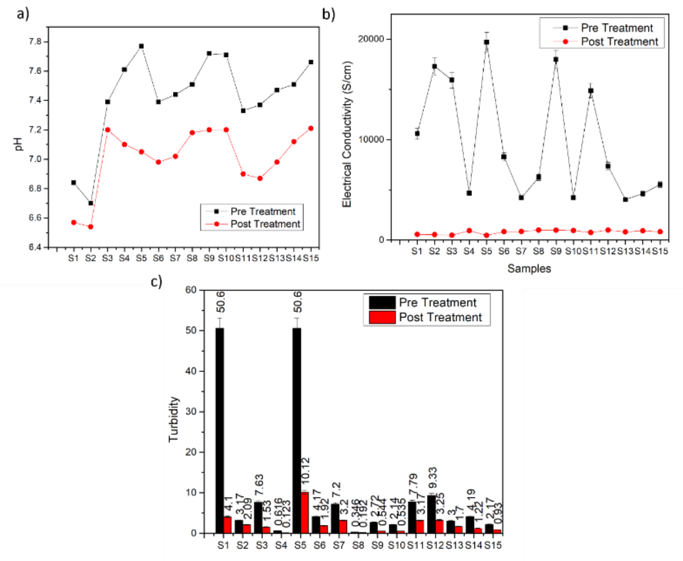

Fig. 3. representing **a)** pH trend **b)** Electrical Conductivity and **c)** Turbidity values in Sargodha city samples.

The range of electrical conductivity was found between 4220 µS/cm to 19720 µS/cm in the groundwaters of Sargodha as shown in Fig. 3b. Electrical conductivity is a measure of the dissolved minerals or solids. Higher Electrical conductivity values reflect high dissolved content [22]. For human health the value of electrical conductivity should not exceed more than 1,500 µS/cm [23]. Electrical conductivity values in S1, S2, S3, S5, S9 and S11 were 10 folds higher than the permissible limit. Post treatment data showed that EC values were lowered in all samples and found between 560 to 987 µS/cm range. The results were found promising as maximum 97.6% decrease in EC was observed in the ground water of sample 5.

Suspended matter contaminants include soil particles, silt, clay, organic matter, phytoplankton, algae, viruses, bacteria, and protozoa and microbes make water colored and turbid. Turbidity makes water opaque and WHO standards have nephelometric turbidity units (NTU) >5 [24]. The filter reduced the turbidity by up to 91.89 % **Fig. 3c** in the groundwater sample S1and S5 with the highest turbidity value observed before treatment. It can be viewed from the results shown in Table 2 and 3 and it may be said that the studied filter found very efficient. For example, in S1 there was 92% removal of the turbidity, and the turbidity value was reduced to the permissible WHO standard value. The variability of results indicates that water samples came across some interference during filtration.

3.4. *Evaluation of Chemical Characteristics of Filtered Water After Treatment*

3.4.1. *Total Dissolved Solids (TDS)*

Total solid is defined as the combination of dissolved solid and suspended solid. Water being universal solvent has minerals and organic molecules, toxic metals dissolved or suspended in it. Some ions such as Ca, Mg and HCO_3 dissolved in water at very low concentration are necessary for human health [25], but industrial and population explosion and surface runoff has led to toxic ions and organic molecules dissolved in water making it unsuitable for drinking purpose. Therefore, WHO has set the maximum dissolved solid to be limit 1000mg/L. TDS more than these values impart bad taste to water thus making it unsuitable. The TDS values greater than 1000 mg/L may cause unnecessary scaling in domestic appliances including boilers, heaters, and water pipelines. Water samples after filtering through a 2.0 µm pore size are evaporated at 180 ºC to obtain dissolved solid. Total dissolved solid was beyond the permissible limit in all the water samples. Total dissolved solids values characterized the drinking water in all the samples to be saline. While S3, S5, S10 and S12 of Sargodha city have 7 to 9 folds higher TDS values than the permissible limit. Post treatment there was a significant removal 80-90% in the dissolved content. Post water treatment these values were found between ~231 to 500 mg/L Fig. 4a.

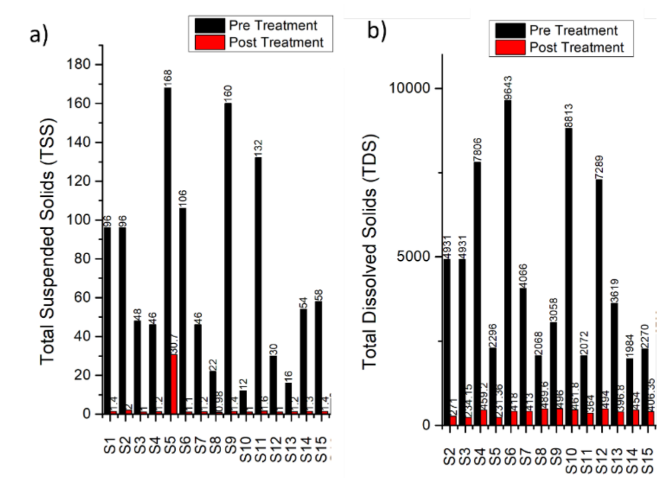

Fig. 4. Pre and Post Trends of a) Total Dissolved Solid b) Total Suspended Solid

3.4.2. *Total Suspended Solids (TSS)*

Total suspended solid was found in the range from 12 to 168 in Sargodha city water samples. Post treatment the values of suspended solid dropped effectively and these values were between 0-1.5 mg/L Fig. 4b.

3.4.3. Total Hardness (TH)

Hardness measure of dissolved polyvalent metallic ions, primarily calcium and magnesium cations, but also others (such as aluminum, barium, iron, manganese, and strontium cations) cations also contribute [26]. When divalent cations and anions interact in water, they frequently form stable salts. The type of anion present in these salts distinguishes between the two types of hardness, carbonate, and non-carbonate.

Excessive calcium is excreted by kidneys by hormonally active form of vitamin D.in healthy humans, it hinders the absorption of iron, zinc, magnesium, and phosphorus in intestine, Excessive magnesium can't be removed from the body thus change the on balance in intestine leading to altered bowel moments resulting in diarrhea. Magnesium concentrations exceeding ~250 mg/l each act as a laxative. Recent reports have brought to light that use of hard water for drinking purpose may lead to various diseases related to heart, kidney and nervous systems. Furthermore these may lead to diabetes, childhood atopic dermatitis, kidney stones, bones related issues, reproductive health, digestive health and constipation [26, 27]. World Health organization (WHO) standard limit is 250 mg/L**.** In Sargodha city drinking water hardness was between 3 to 11 times than the standard limits. Post treatment of this water has been efficient, and all the values of the total hardness are below the standard limit Fig. 5a.

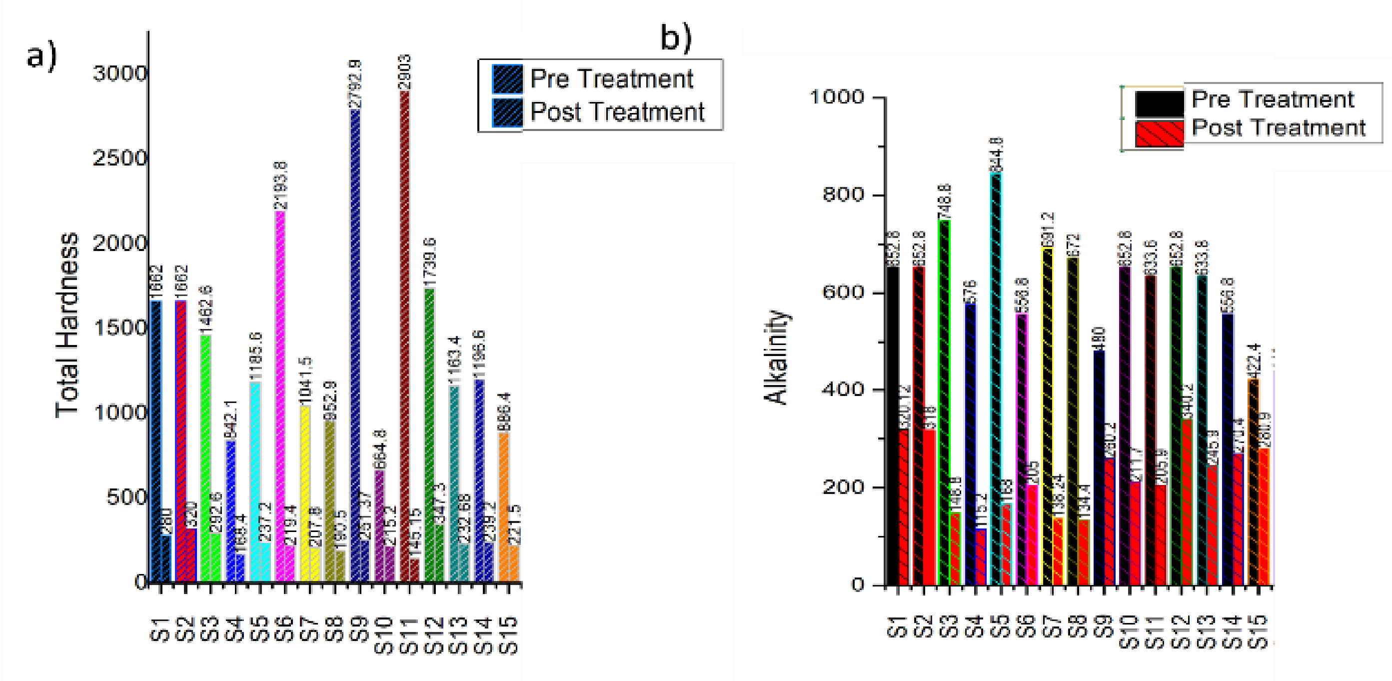

Fig. 5. Treatment Trends of a) Total Hardness and b) Alkalinity

The ability of water to neutralize acids is known as alkalinity, and it is caused by alkaline substances in water like carbonate, bicarbonate, hydroxide, and occasionally borate, silicate, and phosphate.

The alkalinity values ranged between 211.2-844.8 mg/L, post treatment brought these values to 115.2 to 340.2 mg/L Fig. 5b.

Calcium and Magnesium are major ions responsible for the hardness of the water [28]. Graphically these have been represented in Fig. 6. It is clear that Calcium and Bicarbonate are the major contributing ions for the hardness of water.

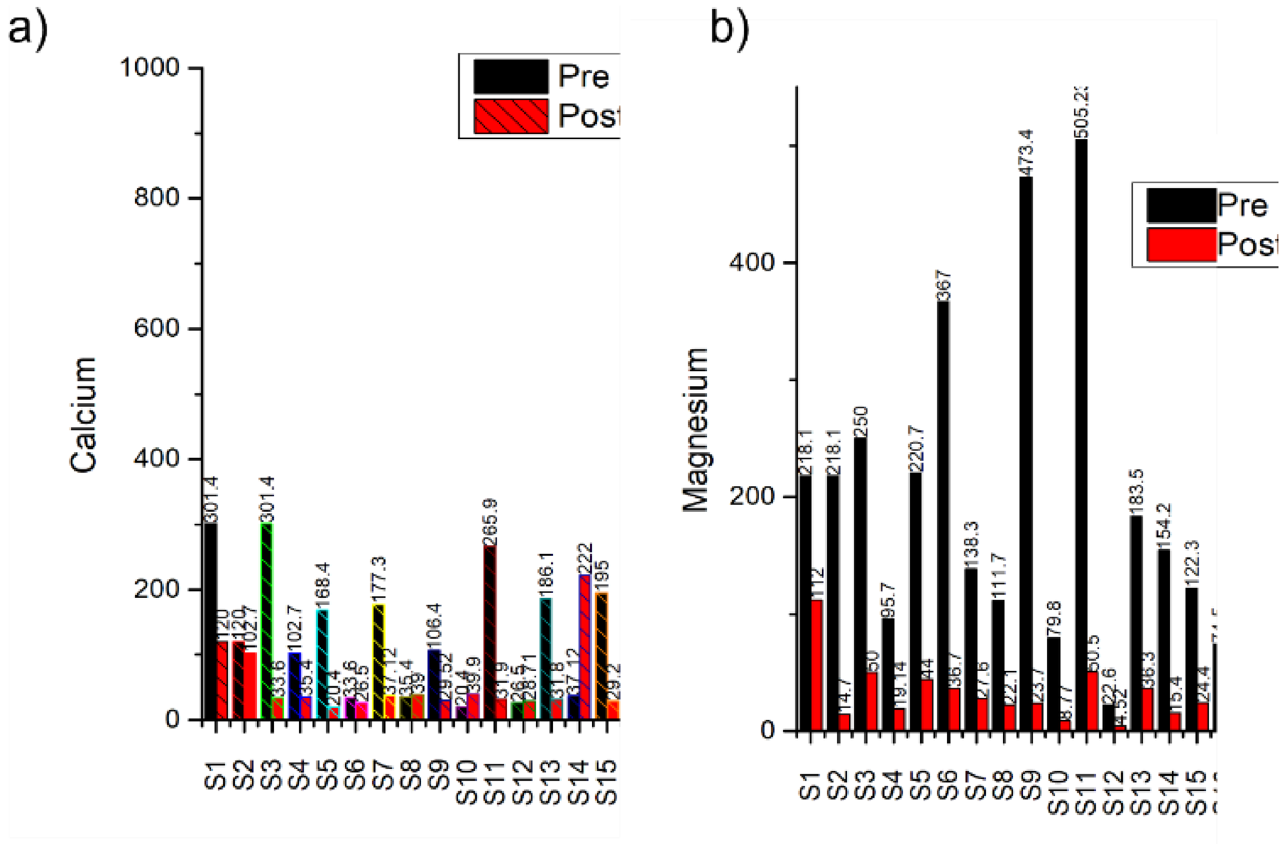

Fig. 6. Representation of cations contributing for water hardness a) Calcium b) Magnesium.

Table 2

Summary of pre- and post- filtration results of HMLSSF in comparison with WHO and NEQS standards for drinking water.

Parameters	Abbreviations	Units	WHO Permissible Levels (2011)	NEQS Limits (2010)	Mean Pre-Treatment Data	Mean Post-Treatment Data	Removal %
pH	pH		6.5-8.5	6.5-8.5	7.4	6.5	87.8
Electrical Conductance	EC	µS/cm	400		9711	793	91.8
Turbidity		NTU	5	5	10.38	2.31	77.7
Total Dissolved Solids	TDS	mg/L	1000	1000	4636	403	91.3
Total Hardness as $CaCO_3$	TH	mg/L	100-500	500	1533	239	84.4
Total Suspended Solids	TSS	mg/L			74	3.4	95.4
Total Alkalinity as $CaCO_3$	TA	mg/L			643	220	65.8
Bicarbonates	HCO3	mg/L			784	268	65.8
Chlorides	Cl	mg/L	250	<250	2023	317	84.3
Sodium	Na	mg/L	200		1155	159	86.2
Potassium	K	mg/L	12		25	2.9	88.4
Calcium	Ca	mg/L	100		355	56	84.2
Magnesium	Mg	mg/L	50		211	32	84.8

The summary of removal performance of major ions along with the physical appearance of groundwater samples from Sargodha has been presented in Table 2 in comparison with the WHO permissible guidelines for drinking purpose. The removal performance of understudy design is very effective for the treatment of polluted water.

3.5. Evaluation of Trace Elements of Filtered Water After Treatment

Heavy metals contamination in the drinking water is of special concern due to their high toxicity even at low quantities. Heavy metals are the most persistent contaminants detected in drinking water of Sargodha are metals or elements with an atomic density of more than 6 g/cm^3. Most heavy metals, unlike organic contaminants, do not decompose and accumulate throughout the food chain, potentially endangering both human health and the ecological equilibrium. Using ICP-MS analysis following 12 metals were detected in in drinking water of Sargodha: Aluminum (Al), Chromium (Cr), Arsenic (As), Manganese (Mn), Iron (Fe), Cobalt (Co), Nickel (Ni), Copper (Cu), Zinc (Zn), and Selenium (Se)

Groundwater contamination due to universally occurring minerals and metals is a major concern for water regulators worldwide. The proposed low-cost fabricated filter comprising carbon; proved to be the good enough solution to these problems as the carbon has ability to remove some chemicals in water because its effective adsorbing ability. According to the world health origination (WHO) drinking water should contain less than the recommended levels of trace elements as shown in Table 3.

Table 3

WHO permissible limit for metals in drinking water.

Metals	WHO permissible drinking water limit (mg/L)
Aluminum	0.2
Chromium	0.05
Arsenic	0.01
Manganese	0.1
Iron	0.3
Cobalt	--
Nickel	0.02
Copper	2
Zinc	3.0
Selenium	0.01
Cadmium	0.003
Lead	0.00005

Following the filtration experiments, the treatment results with reference to trace element are shown in Table 4. The removal performance was promising enough against trace and heavy metals understudy. Aluminum was removed up to 78%in sample S 9. 96% of Selenium was removed as compared to raw water collected from location S10. Similarly, 0.606mg/L Zinc was removed up to 0.015mg/L, Copper from 0.463mg/L to 0.001mg /L. Iron at 0.4 mg/L level was completely removed.

Table 4

Treatment profile of trace elements under study

Samples	Al(ppm)			Cr(ppm)			As(ppm)			Mn(ppm)			Fe(ppm)			Co(ppm)			Ni(ppm)			Cu(ppm)			Zn(ppm)			Se(ppm)		
	Pre-Treatment	Post Treatment	% Removal	Pre-Treatment	Post Treatment	% Removal	Pre-Treatment	Post Treatment	% Removal	Pre-Treatment	Post Treatment	% Removal	Pre-Treatment	Post Treatment	% Removal	Pre-Treatment	Post Treatment	% Removal	Pre-Treatment	Post Treatment	% Removal	Pre-Treatment	Post Treatment	% Removal	Pre-Treatment	Post Treatment	% Removal	Pre-Treatment	Post Treatment	% Removal
S1	0.051	0.021	58.824	0.001	0.000	100.000	0.002	0.000	100.000	0.433	0.021	95.150	0.040	0.000	100.000	0.002	0.001	50	0.017	0.000	100.000	0.004	0.001	75.000	0.196	0.004	97.959	0.008	0.001	87.500
S2	0.047	0.018	61.702	0.002	0.000	100.000	0.001	0.000	100.000	1.209	0.009	99.256	0.037	0.000	100.000	0.003	0.001	66.66667	0.007	0.000	100.000	0.012	0.001	91.667	0.130	0.000	100.000	0.003	0.001	66.667
S3	0.018	0.017	5.556	0.001	0.000	100.000	0.000	0.000	0	0.009	0.001	88.889	0.002	0.002	0.000	0.001	0.001	0	0.000	0.000		0.001	0.001	0.000	0.006	0.004	33.333	0.001	0.001	0.000
S4	0.050	0.017	66.000	0.001	0.000	100.000	0.002	0.000		0.588	0.045	92.347	0.037	0.000	100.000	0.002	0	100	0.016	0.002		0.005	0.001	80.000	0.606	0.015	97.525	0.008	0.001	87.500
S5	0.040	0.017	57.500	0.001	0.000	100.000	0.002	0.000	100.000	0.041	0.015	63.415	0.031	0.000	100.000	0.001	0.001	0	0.017	0.000	100.000	0.004	0.001	75.000	0.251	0.003	98.645	0.003	0.001	66.667
S6	0.044	0.017	61.364	0.001	0.000	100.000	0.001	0.000	100.000	0.264	0.015	94.318	0.033	0.000	100.000	0.001	0.001	0	0.009	0.000	100.000	0.003	0.001	66.667	0.050	0.003	93.200	0.002	0.001	50.000
S7	0.044	0.019	56.818	0.001	0.001	0.000	0.001	0.000	100.000	0.264	0.019	92.803	0.033	0.000	100.000	0.001	0.001	0	0.009	0.000	100.000	0.003	0.001	66.667	0.050	0.004	92.000	0.002	0.001	50.000
S8	0.048	0.016	66.667	0.003	0.002	33.333	0.002	0.000	100.000	0.040	0.005	87.500	0.036	0.000	100.000	0.006	0	100	0.005	0.000	100.000	0.004	0.001	75.000	0.106	0.003	97.170	0.010	0.001	90.000

S9	0.041	0.009	78.049	1.658	0.002	99.879	0.001	0.000	100.000	0.002	0.000	100.000	0.029	0.000	100.000	0.001	0	100	0.004	0.000	100.000	0.003	0.001	66.667	0.136	0.004	97.059	0.010	0.001	90.000
S 10	0.030	0.009	70.000	0.009	0.000	100.000	0.002	0.000	100.000	0.002	0.001	50.000	0.028	0.000	100.000	0.002	0.001	50	0.002	0.000	100.000	0.002	0.001	50.000	0.139	0.002	98.561	0.028	0.001	96.429
S 11	0.028	0.015	46.429	0.001	0.000	100.000	0.003	0.000	100.000	0.174	0.031	82.184	0.025	0.000	100.000	0.002	0.001	50	0.004	0.000	100.000	0.004	0.001	75.000	0.356	0.012	96.629	0.018	0.001	94.444
S 12	0.035	0.016	54.286	0.001	0.000	100.000	0.001	0.000	100.000	0.665	0.014	97.895	0.032	0.000	100.000	0.002	0.001	50	0.004	0.000	100.000	0.004	0.001	75.000	0.254	0.029	88.583	0.008	0.001	87.500
S 13	0.034	0.012	64.706	0.001	0.000	100.000	0.001	0.000	100.000	0.103	0.004	96.117	0.035	0.009	74.286	0.001	0.001	0	0.008	0.000	100.000	0.008	0.001	87.500	0.620	0.004	99.355	0.006	0.001	83.333
S 14	0.033	0.016	51.515	0.011	0.006	45.455	0.001	0.000	100.000	0.007	0.002	71.429	0.033	0.000	100.000	0.033	0.001	96.9697	0.008	0.000	100.000	0.463	0.001	99.784	0.003	0.002	33.333	0.003	0.001	66.667
S 15	0.037	0.016	56.757	0.013	0.001	92.308	0.001	0.000	100.000	0.435	0.009	97.931	0.032	0.000	100.000	0.002	0.001	50	0.003	0.000	100.000	0.003	0.001	66.667	0.145	0.002	98.621	0.001	0.001	0.000

3.6. Microbiological Evaluation of Heavy Metals of Filtered Water After Treatment

Slow sand filtration is recognized for the removal of pathogenic bacteria, viruses, suspended solids, and turbidity, the designed filtration was practiced on the waters of Sargodha. The outcomes of the biological analysis are shown in Table 5. The Total Plate Count (TPC) readings in every water sample is nil in all the sample of the Sargodha city. Both fecal and environmental organisms are included in the Total Coliform (TC) group [29]. Existence of microbes indicates that soil, plant detritus, and human feces had all contaminated the water. Table 8 shows that the sample's water was polluted with TC. It is also important to note that the sample S7 was contaminated with E. coli. This contamination can be attributed to several factors, including the intermittent water supply of wastewater into the distribution system through weak joints, the mixing of sewage water with fresh water, the dumping of garbage in the soil, and the mixing of ground water with sewage water.

Table 5

Microbiological Analysis of ground waters from Sargodha

Sample ID		TPC	T. Coliform	F. Coliform	E. Coli
S1	Pre-Treatment	Nil	<2	<2	Not Detected
	Post Treatment	Nil	<1	<1	Not Detected
S2	Pre-Treatment	Nil	<2	<2	Not Detected
	Post Treatment	Nil	<1	<1	Not Detected
S3	Pre-Treatment	Nil	<2	<2	Not Detected
	Post Treatment	Nil	<1	<1	Not Detected
S4	Pre-Treatment	Nil	<2	<2	Not Detected
	Post Treatment	Nil	<1	<1	Not Detected
S5	Pre-Treatment	Nil	<2	<2	Not Detected
	Post Treatment	Nil	<1	<1	Not Detected
S6	Pre-Treatment	Nil	<2	<2	Not Detected
	Post Treatment	Nil	<1	<1	Not Detected
S7	Pre-Treatment	Nil	Nil	<2	<2
	Post Treatment	Nil	Nil	<1	Not Detected
S8	Pre-Treatment	Nil	<2	<2	Not Detected
	Post Treatment	Nil	<1	<1	Not Detected
S9	Pre-Treatment	Nil	<2	<2	Not Detected
	Post Treatment	Nil	<1	<1	Not Detected
S10	Pre-Treatment	Nil	<2	<2	Not Detected
	Post Treatment	Nil	<1	<1<1	Not Detected
S11	Pre-Treatment	Nil	<2	<2	Not Detected
	Post Treatment	Nil	<1	<1	Not Detected
S12	Pre-Treatment	Nil	<2	<2	Not Detected
	Post Treatment	Nil	<1	<1	Not Detected
S13	Pre-Treatment	Nil	<2	<2	Not Detected
	Post Treatment	Nil	<1	<1	Not Detected
S14	Pre-Treatment	Nil	<2	<2	Not Detected
	Post Treatment	Nil	<1	<1	Not Detected
S15	Pre-Treatment	Nil	<2	<2	Not Detected
	Post Treatment	Nil	<1	<1	Not Detected
WHO Levels	CFU/ml	Zero	Zero	Zero	Negative

3.7. Comparison of Present Study with The Previously Published Studies of Sand Filtration

Sand filtration is one of the oldest treatment techniques to remove several chemical, physical and microbial contaminants. There have been advancements in using contemporary slow sand filtration for water treatment technology and knowledge continue to be applied in present century. The sand filtration treatment process is now applied with and some development in household drinking and wastewater and industrial water treatments in combination with chlorination most often employed, as the complete removal of pathogens.

In comparison with other studies regarding the application of sand filters with various modifications; hybrid multilayer slow sand filter (HMLSSF) treatment has been found to be promising for the removal of contaminants from the ground waters of Sargodha city Table 6. There is no sufficient data found on the removal of TDS and other main nutrients, but this research presents complete treatment solutions of ground/brackish water up to the permissible limits by WHO for drinking water Table 3.

The novelty of this work lies in the development and application of a unique filtration system, the lack of prior data in the specific context of studying, and the achievement of comprehensive treatment solutions that meet drinking water quality standards.

Table 6

Contaminant removal by various sand filters

Parameter/Contaminant	Filter	Removal Performance	Reference #
Chemical Removal			
Total organic matter, Turbidity	ultrafiltration and a sand filter	48.8%, 40.3%	[31]
Ca, Mg	Bio Sand Filter	78.7%	[32]
Mn, Fe	Rapid sand filter	95 %	[33]
Fe, Mn	Aeration and quick natural sand filtration	98.44%, 97.3 %	[34]
Turbidity	0.2–0.3 mm sand (1.05 m) in Field.	Average 55%, effluent < 1.1 NTU	[35]
Turbidity	0.3–2.33mm sand (0.45 m) in PVC Columns	89 %	[36]
Arsenic	Sand Filter	89 %	[37]
Turbidity, Ca, Mg, Fe, Mn, As	Hybrid Multilayer Slow Sand filtration	77.7%,84.2%,84.8%,100%, 99.3%, 100% respectively	[Present Study]
Microbial Removal			
Total coliforms and E-coli.	Sand Filter	60 %	[38]
Total coliforms	Sand Filter	100%	[39]
Total coliforms and E-coli.	Hybrid Multilayer Slow Sand filtration	100%	[Present study]

4. Conclusion

In this approach a water treatment design was fabricated from locally available indigenous materials based on slow sand filtration. The real sample application was then performed on the ground waters of Sargodha city. The process found to be economic, ecofriendly and easy to use. We anticipated that these filtration assembly based on local materials grass, sand, pebbles, sand, gravel, sand, and coal would help in the control of physical, chemical, and biological properties of water.

Based on the groundwater type of Sargodha city, the results were found promising enough. The proposed filter in this study reduced E-Coli count by 99 to 100% effectively as most of the other slow sand filters could not totally remove Fecal coliform and pathogens from the water to make high contaminated water by pathogens safe for consumption. It is recommended that the performance of filter may be improved by using the settled water rather than the raw water directly. Furthermore, this may be helpful in increasing the life of filter.

Depending upon the water quality and its environment the filtration assembly may be effective for removal of unwanted species by modifying the media size, bed depth, filtration rate, biological maturity of the filter and cleaning practices.

The financially weak communities may also benefit with the proposed water filtration System based on its indigenous and economical fabrication, and thereby, can put a substantial role in protecting and improving the public health. The main components of the system are accessible and easy to build and maintain. Furthermore, with small efforts, less skills and few technical trainings, these filtration systems may be spread and experienced.

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