

# Performance Analysis of Water Filtration Units for Reduction of pH, Turbidity, Solids and Electricity Conductivity

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**Abstract**—The main objective of this study was to analyze the performance of different filtration units that reduce turbidity, pH, total dissolved solids (TDS) and electrical conductivity (EC) of canal water. For that, three different types of filtration units, namely, slow sand, rapid sand and dual media were fabricated. Typical parameters of canal and filtered water, like pH, turbidity, TDS and EC were examined, and then the filtered water quality was compared with World Health Organizations (WHO) standards. Maximum pH reduction was noted with dual media and less by the rapid system, while more turbidity was reduced with the slow sand and less with the dual media filtration system. In contrary to the pH and turbidity results, increment in both TDS and EC values were noted in filtered samples compared to that of raw water samples due to the transfer of dissolved minerals present in the sand into the filtered water during the contact period with media in the bed. However, all examined parameters of filtered water were within WHO standards.

**Keywords**—water filtration; pH; turbidity; water quality

## I. INTRODUCTION

Water covers about 71.4% of the surface of the planet. Pure water has no smell, taste, or color. Potable (drinking) water is safe to drink or to use for other purpose like food preparation etc. [1]. Clean water is a crucial requirement for a healthy life but, globally, almost more than 1.1 billion people can't reach safe water sources. Today, the worst victims of the water crisis are the populations of low and middle income countries [2, 3]. Globally, each day, women and children spend almost 200 million hours on collecting often polluted water from distant water sources [2, 4]. The impact of unsafe drinking water not only has devastating effects to individuals and families, but

over the society as a whole [2]. The primary sources of drinking water in Pakistan include groundwater, rivers, lakes and canals. The canals are the most important source for the nearby population [5, 6]. The causes behind the degradation of water quality are mainly anthropogenic activities. However, an improved management system and implementation of different physical, chemical or biological techniques could help significantly to control the degradation [7, 8].

Authors in [9] reported that the major reason behind almost 80% of ailments and more than 33% of deaths in developing countries is polluted water. Among 122 nations with poor drinking water quality, Pakistan ranks at number 80 [10, 11]. Moreover, due to the absence of water treatment systems, the survival of a substantial portion of Pakistan's rural population relies on ground water sources. According to the reports, around 40% of the deaths in Pakistan are a result of water borne diseases [12]. In the surface water bodies of Pakistan 2000 million gallons of sewage are dissolved per day [13]. It has been reported that the percentage of people having access to safe drinking water in Pakistan is just 60% [14]. By 2015, according to government's set target, 93% of the population should be having access to safe drinking water, where by 2025, the entire population will have such provision [15, 16]. However, the target is not so easy to achieve and is challenging due to many economic, technical and political problems.

The use of sand filters for domestic purposes has increased around the world for understanding the mechanisms for microbial control [17, 18]. Color and turbidity (darkness of water due to suspended particles) are major properties therefore turbidity removal from canal water is important [19, 20]. Locally developed sand filters have been proved to be a cost

effective and efficient solution towards removal of solids from the raw water [18]. Therefore, the main goal of this study was to develop less expensive water treatment filters for PH, turbidity and solids and electricity conductivity reduction using locally available materials to remove the suspended particles from canal water.

## II. MATERIALS AND METHODS

This study's aim was to design and develop cheap water treatment systems from locally available materials in order to remove the pollutants/suspended particulates from canal waters. Therefore, a slow, rapid and dual media filtration system was designed and fabricated for removing the pollutants/suspended particulates and turbidity from canal water and make it fit for human consumption in remote areas of the country where the conventional treatment plants are not available.

### A. Water Sampling

The water samples were collected from Rohri Canal using plastic drums with a capacity of approximately 1800 liters. Sampling was carried out in the morning time around 08:00 AM Pakistan Standard Time (PST).

### B. Development of Slow, Rapid Sand Bed Filtration and Dual Media Filtration System

Fundamentally, all water treatment technologies focus on removing turbidity along with chemical and pathogenic contaminants from water with the most efficient and affordable way possible. Natural settling using sand filtration is the most common type of natural filtration used today. Such a filtration method has proved to be an excellent method and therefore is being used since nineteenth century [21]. Therefore, in this study, three different filtration systems (slow sand bed, rapid sand bed and dual media filtration systems) were adopted and utilized in order to remove pollutants from canal water. The filters were prepared from local materials (plastic drums). Each filtration system unit comprised of water reservoir, top cover, diffuser plate, main treatment unit and riser pipe. Additionally, a plastic drum with a capacity of 1800 liters was used to hold the huge amount of canal water initially. The filtration system was designed and fabricated in Mechanical Engineering Department, and it was tested in Energy and Environment Engineering Department of QUEST Nawabshah.

### C. Analyzing of Water Quality Parameters

The pH level of sampled water (before and after) was examined through a Lovibond Senso direct pH 110 meter. ELE Microprocessor Turbidity Meter was used to analyze the turbidity level, electrical conductivity was measured with ELE International Conductivity Meter and total dissolved solids (TDS) were measured by TDS meter Model HI98302 by HANNA in the Laboratory of Energy and Environment Engineering Department, Quaid -e- Awam University of Engineering, Science and Technology (QUEST), Nawabshah.

## III. RESULTS AND DISCUSSION

A total of four parameters, namely, turbidity, pH, TDS and EC of Rohri canal water were examined. As shown in Table I, pH of the raw water was 8.4, whereas, pH of filtered water by

rapid sand was 8.3, slow sand 7.8 and dual media 7.6. The WHO guideline value of pH is 6.5-8.5. It was found that dual media percentage of pH reduction was greater than that of slow sand and rapid sand bed filtration systems. The average turbidity values of raw canal water and filtered water are also shown in Table I. Turbidity level of raw water was 522.5FTU, whereas, its level was 55.1, 25.3 and 4.8FTU with dual media, rapid sand and slow sand filtration system respectively). Slow sand bed filtration unit was found more effective in reducing turbidity level (the WHO guideline value of turbidity is 5FTU). TDS level in raw canal water was 47mg/l as shown in Table I. TDS value in filtered water was 155mg/l with dual media, 145mg/l with slow sand and 68mg/l with rapid sand filtration system, whereas the acceptable WHO guideline for TDS is 1000mg/l. Dual media filtration system was found less effective and rapid sand more effective in reducing TDS. The EC results of raw as well as filtered water samples are shown in Table I. The values of EC of raw water were 78.6 $\mu$ S/cm. The EC of filtered samples were more than that of raw water. EC values were found increased by 230% with dual media, 204% with slow sand and 45% with rapid sand method compared to raw water. It is noted that rapid sand filtration system is more effective in reducing EC from raw water than other examined systems. It is deduced from the results that both TDS and EC showed increasing behavior in filtered water. The increase of TDS resulted in rise of EC and vice versa, therefore both are interrelated.

TABLE I. ROHRI CANAL WATER PARAMETERS

Treatment System	pH	Turbidity (FTU)	TDS (mg/l)	EC ( $\mu$ S/cm)
Slow sand filter	7.8	4.85	145	239
Rapid sand filter	8.3	25.29	68.5	114.1
Dual media filter	7.6	55.1	155	259
Feed water	8.4	522.5	47.2	78.6

An economic analysis of the filtration unit development, materials used, and the quantity of water filtered is carried out under the current study. Table II details the economic analysis of the materials used in the water filtration units. The total cost amounts to Rs. 3700. This includes water drum, sand, gravel, charcoal, and piping system. The cost of sand filter is given in Table III. The quantity of liters filtered in a single day is 2, this makes it to 720 liters per year, as shown in Table IV. On the basis of water filtered using this unit, the payback period calculated for the sand filter is 1.9, approximately 2 years. The replacement cost of sand, used as a filter, is 140 Rs. per month, the layer value of sand is 60 Rs., whereas the cost of the coarse and fine gravel is 40 Rs. each.

TABLE II. ECONOMIC ANALYSIS OF THE FILTRATION UNIT

Items	Quantity	Cost/item	Total Cost
Drum	3	800	2400
Sand	5-Tin	30	150
Coarse gravel	3-Tin	40	120
Fine gravel	3-Tin	40	120
Charcoal	5 kg	20	100
Pipe (0.75")	10 feet	20	200
Tape wall	3	50	150
Miscellaneous items	10	--	500
			<b>3740</b>

1 Tin = 15kg

The cost of the whole process of water filtration per liter is estimated to be 2.33 Rs. (see appendix for details), therefore the cost per year is estimated to be 1677 Rs.. Comparatively, the price of water purchased from the local market costs 30 Rs. per liter, whereas the annual consumption/annual filtration of water is 720 liters, therefore the total price of water becomes 21600 Rs. per year. On comparing the cost of water purchased from the local market and the water filtered using the filtration unit developed under this research study, it is estimated that 20230 Rs. per year can be saved, which is the difference between yearly expenditure on the filtration unit and the cost of the purchased water.

TABLE III. CAPITAL COST OF ONE FILTER (SLOW SAND)

Items	Quantity	Cost/item	Total Cost
Drum	1	800	800
Sand	2-Tin	30	60
Coarse gravel	1-Tin	40	40
Fine gravel	1-Tin	40	40
Pipe (0.75")	4 feet	20	80
Tape wall	1	50	50
Miscellaneous items	5	0	300
			1370

TABLE IV. QUANTITY OF FILTERED WATER

Parameter	Daily (ltr)	Monthly (ltr)	Yearly (ltr)
Treated water/ Distilled water	2	60	720

On the basis of the above results it was found that the slow sand filter was significantly better than the other filter systems. However, there is still some gap to further improve the performance of slow sand filter, e.g. of layers of different materials can be used in the construction. This shall help control the performance enhancement of slow sand filters.

#### IV. CONCLUSIONS

Dual media filtration system was found more suitable for raw water pH reduction. In addition, slow sand bed filtration unit was found more effective in reducing turbidity. In contrary to the pH and turbidity of raw water, the level of TDS and EC showed increasing behavior in filtered water comparing with raw water samples. It was observed that 108mg/l, 98mg/l and 21mg/l more TDS was noted in filtered water by application of dual media, slow sand and rapid sand bed filtration system respectively. Similarly, EC of filtered water was increased approximately by two and a half times with dual media, two times with slow sand and only half time by rapid sand method. TDS and EC are found interrelated as the increase of TDS results to increase of EC and vice versa. It was discovered that dual media filtration system was found less effective and rapid sand more effective in reducing TDS and EC among the examined methods.

#### APPENDIX

##### Replacement Cost of Sand and Gravel

Layer value of sand	60 Rs.
For SSF (slow sand filter) coarse gravel	40 Rs.
For SSF (slow sand filter) fine gravel	40 Rs.
The replacement cost of sand and gravel	140 Rs./month

Cost per ltr	(140/60)	2.33 Rs./ltr
Cost per month	(2.33*60)	140 Rs./month
Cost per year	(2.33*720)	1677.6 Rs./year

##### Water price in Local Market

Water per liter in local market		30 Rs.
Monthly water price	(30*60)	1800 Rs./month
Yearly water price	(30*720)	21600 Rs./year

##### Comparison of Filtered Water vs Purchased Water

Profit = (Yearly expenditure of purchased water- Yearly expenditure of SSF water)		
Profit		= (21600-1370)
Profit		20230 Rs

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