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OPTIMIZING RIVER WATER FILTRATION: IMPROVING MULTIMEDIA FILTER DESIGN FOR EFFICIENT FILTRATION

A THESIS SUBMITTED BY
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APPROVAL

The Paper titled “Optimizing River water Filtration: Improving Multimedia filter Desing for Efficient Filtration “submitted by Md. Iqramul Haque Emon, Md. Asir Ahabab has been accepted partial attainment of the requisite for the degree, Bachelor of Science in Civil Engineering.

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DECLARATION

It is hereby declared that this thesis/project report, in whole or in part, has not been submitted elsewhere for the award of any Degree or Diploma.

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DEDICATION

We thank our family and teachers for their support and belief in us.

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ABSTRACT

Modern and effective water filtration techniques are required due to the growing pollution of river water caused by industrial discharge, agricultural runoff, and urbanization. The goal of this work is to improve the efficiency of river water filtration through the design of multimedia filters. Our approach aims to remove physical, chemical, and biological contaminants more effectively by combining different filtration media with unique properties. The study focuses on optimizing the arrangement and choice of filtration materials, such as sand, anthracite, and gravel, and examines their impact on flow rates, maintenance needs, and filtration efficiency.

Experimental analysis shows that the optimized filter design achieved up to 73% reduction in turbidity, 74.6% removal of color, and a maximum of 35% decrease in Chemical Oxygen Demand (COD). The aim is to develop a multimedia filter design that maximizes contaminant removal efficiency while minimizing energy and maintenance costs.

The results offer new perspectives on optimizing multimedia filters for treating river water. The optimized filter design is suitable for both urban and rural applications, providing an affordable and environmentally friendly solution to improve water quality. This study advances environmental engineering and protects public health by ensuring safer water for communities dependent on rivers for their daily needs.

CHAPTER 1: INTRODUCTION

1.1 Background

An essential resource for human health and well-being as well as environmental sustainability is water, and its quality is critical to both. Since rivers are a major source of freshwater, pollution from urban effluents, agricultural runoff, and industrial discharges is becoming more prevalent. It is therefore more important than ever to have dependable and effective water filtration systems.Some of the most frequent problems in the water supply sector are prevented by filtration; they include color, turbidity, and dangerous microbes. Furthermore, filtration is a key component of the multi-barrier strategy used to remove microorganisms.(Cescon & Jiang, 2020)While simple media like sand and gravel are effective in some cases, they may not offer the thorough filtration needed to address the complex and varied contaminants present in river water. This is because traditional water filtration methods frequently use them. The filtration system that is currently in place, as it pertains to this study, is composed of gravel and sand and is angled five degrees toward the river. The purpose of this configuration is to reduce turbidity and remove particulate matter by utilizing gravity to facilitate the flow of water through the filter media. The effectiveness of sand and gravel filters in removing heavy metals, chemicals, and microbiological contaminants is restricted, despite their usefulness in removing basic sediment. The need to optimize filter design in order to improve overall filtration efficacy is highlighted by this limitation.

In particular, by maximizing the use of sand and gravel in conjunction with other filtration media, the main goal of this research is to investigate and apply improvements in the multimedia filter design. Investigating how different filter media configurations, inclination angles, and flow rates affect contaminant removal efficiency is the goal of this study. This research aims to create a more efficient filtration system that can produce water of a higher quality, potentially improving public health and protecting the environment. It does this by utilizing both experimental and computational methods.

1.2 Problem Statement

A major obstacle to preserving water quality is the rising pollution levels in river water caused by urbanization, agricultural runoff, and industrial discharge. When it comes to chemical pollutants, heavy metals, and microbes, traditional filtration systems that rely on sand and gravel as media aren't up to the task. Because of this inefficiency, communities that depend on river water are exposed to potentially toxic pollutants, which poses a risk to public health and the environment.

The filtering capacity and effectiveness of current sand and gravel filters are limited, especially those that are inclined at a 5-degree angle towards the river. Their effectiveness in dealing with smaller and more varied pollutants is insufficient, while they are helpful in lowering turbidity and bigger particulate removal. Improving the arrangement of current materials and incorporating new filtration media into multimedia filter designs is a challenge with the goal of optimizing filtering efficiency. To make sure communities have safer and cleaner water, we need to find a better way to filter river water, which can handle a complicated combination of toxins. A sustainable and cost-effective solution for river water filtration can be proposed by identifying the ideal combination and arrangement of filtration media and evaluating the influence of different operational parameters.

1.3 Objectives

I. Determine the filters ability to change the physical and chemical parameters river water.
II. Assess the efficiency of the existing sand and gravel filtration system with a 5-degree inclination in removing various contaminants from river water.
III. Evaluate the long-term sustainability of the optimized filtration system, considering factors such as durability, operational costs, and environmental impact.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Physical and chemical processes are both thought to be involved in water filtering. Here we show and analyze experimental evidence pertaining to the chemical components of water filtration. (O'Melia & Stumm, 1967) .With strict regulations in place to ensure the safety of drinking water, the removal of particulate materials from surface water have become an important topic. The filtration of water using granular bed porous media is one of the most popular and effective particle separation processes that have been around for a long time. (Roy & Ghosh, 2023)

2.2 River water And Quality Challenges

The Turag-Tongi-Balu river system is one of the polluted in the world (Whitehead, Bussi, Hossain, & Das, 2018). The river water pollution surrounding Dhaka city is largely caused by the toxic wastewater that is discharged by thousands of factories, including tanneries and metal factories.(Asaduzzaman, Hasan, & Kabir, 2016).The use of contaminated river water for irrigation purposes in agricultural fields increases the danger to human health when we eat rice and other crops grown in these fields.(Han & Zhou, 2020).A number of studies have evaluated the Turag and other peripheral rivers' water quality in light of the increasing surface water challenges in the Bangladeshi megacity. Most of the untreated effluent that ends up in these rivers originates from cities and businesses(Rahman & Hossain, 2008).The unfortunate consequence of the fast urbanization in the Dhaka area is the careless discharge of household rubbish into the Tur.ag River. When water quality declines, it's because of things like organic debris, plastic trash, and human waste, which raises the levels of BOD and COD. Rivers in the catchment region often have fertilizers, insecticides, and herbicides washed down by runoff from nearby farms. In aquatic environments, these compounds trigger nutrient loading, which in turn causes eutrophication and destructive algal blooms. Because to building along its banks and soil erosion upstream, the Turag River experiences considerable sedimentation. Sediment loads have a multiplicative effect on water pollution because they lower river depth and flow and transport adsorbed contaminants.

2.3 Advantages of Multimedia Filters

The importance of wastewater filtration is growing as rules like the Water Framework Directive mandate increasingly stringent water quality criteria for wastewater released into the environment. Nutrients like phosphorus, which are suspended in discharged wastewater, can contaminate the ecosystem and lead to eutrophication in surface waterways. Particle surfaces may be infected by viruses and bacteria, and suspended solids provide a platform for their survival and transportation.(Ncube & Pidou, 2017).Multimedia filters are great at eliminating a broad variety of pollutants because they use many layers of filtering media, including sand, anthracite, gravel, and activated carbon. In comparison to single-media filters, they remove a wider range of contaminants, such as organic compounds, bacteria, heavy metals, and suspended particles. The layered nature of multimedia filters allows them to remove turbidity and small particles more efficiently, leading to cleaner, clearer water. Filter life, improved pollutant capture and retention, and reduced filter clogging are all outcomes of the different kinds and sizes of media layers. Multimedia filters boost filtering performance and extend filter life, which in turn reduces operational expenditures of water treatment. Decreased maintenance and media replacement frequency could lead to long-term cost savings. Although they employ three distinct kinds of media, triple-layer filters are conceptually comparable to dual-layer filters. Gravel, sand, and garnet are among the many media types utilized in these filters. Particle size reduces and specific density increases with increasing depth because of the arrangement of the media components. These are upgraded dual-layer filters that increase water quality and last longer in operation.(Noredinvand & Takdastan, 2021)

2.4 Economic and Environmental Considerations

The conventional methods for assessing water treatment plants have focused on the effectiveness in removing important parameters and the cost of operational activities. However, due to the significant impact of this factor, these methods now need to be supplemented with a verification of the process's overall compatibility.(FABIAN & NEDEFF, 2009)Governments, industry, civil society, and people must work together to create and implement sustainable policies and practices if we are to achieve sustainable development in respect to water pollution. Some examples of such actions include encouraging sustainable farming methods, enhancing wastewater treatment, and decreasing the use of dangerous chemicals.(Sahoo & Goswami, 2023).In order to accomplish water resource-related sustainable development goals and lessen water pollution, the study suggested sustainable development practices including managing and treating wastewater better, regulating industrial wastewater discharge more strictly, and encouraging the use of clean production technologies.(Sahoo & Goswami, 2023)

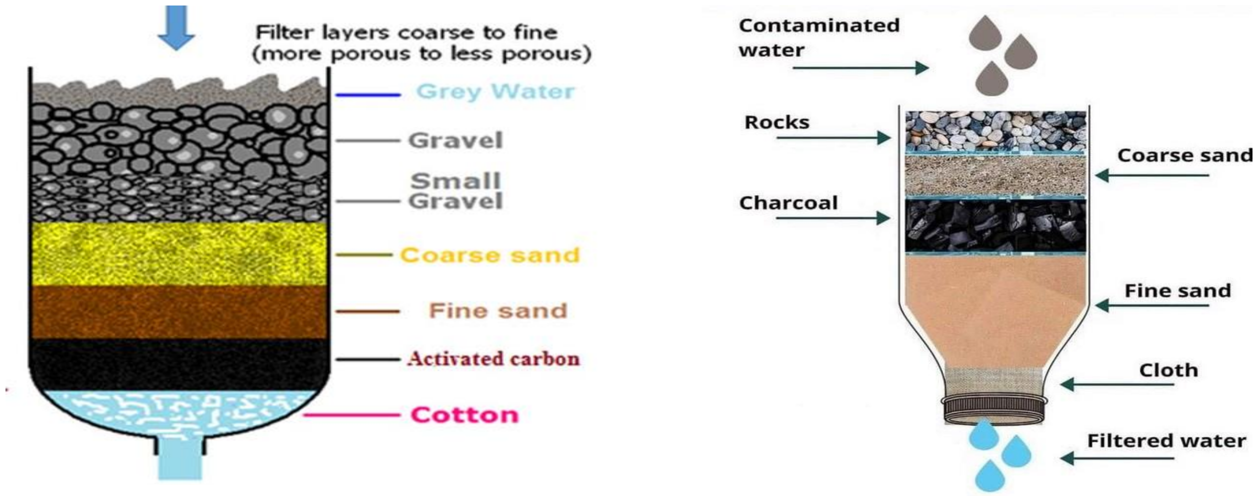

Fig 2.1:Multimedia Filter (Samayamanthula, Sabarathinam, & Bhandary, 2019)

CHAPTER 3: METHODOLOGY

3.1 Introduction

This research primarily aims to enhance the design of multimedia filters so that they can efficiently filter water from rivers, particularly the Turag River. Improving the arrangement of filter media is the main emphasis in order to enhance the filtering performance. The objective of this research is to build a filter that efficiently traps three different types of pollutants using three separate sections of filter material. We intend to create a strong filtration system that guarantees safe and clean water by methodically testing the filtration efficiency of each part and the whole.

3.2 Construction of Filter

The multimedia filter is a horizontal unit that is inclined at a 5-degree angle to allow for flow that is helped by gravity. To improve filtration and allow particles to settle, the filter is divided into three separate layers, each 5 inches long, with a 10-inch space between them.

Segment 1: The first segment, located at the top, is filled with fine sand. This layer acts as the primary filtration medium, effectively capturing fine particles and reducing turbidity in the water.

Segment 2: Below the sand layer, the second segment contains fine gravel. This layer serves to trap medium-sized particles that may have passed through the sand layer, further refining the filtration process.

Segment 3: The third and final segment, situated at the bottom, consists of medium gravel. This layer provides additional filtration by capturing larger particles and serving as a support for the upper layers.

A long-lasting, inert cylindrical container holds the filter media. To keep the 10-inch gap and offer stability, a perforated plate separates each segment. Starting with the medium gravel layer at the base, the fine gravel layer in the middle, and the sand layer on top are the steps in the assembly process. Careful leveling of each layer eliminates channeling and guarantees uniform distribution. The achievement of good filtration and the longevity of the filter system depend on this methodical arrangement of filter material.

Table 3.1: Preparation of Filter

Filter Media	Particle Size(mm)	Volume(in^3)	Amount(kg)
Sand	Fine sand(0.3mm)	125.66	1
	Coarse sand(0.6mm)	125.66	1
Gravel	Fine gravel(2.36mm)	125.66	1
	Fine gravel(4.75mm)	125.66	1
Gravel	Medium gravel (9.5mm)	125.66	1
	Medium gravel(12.5 mm)	125.66	1

Figure 3.1 : Sand Media

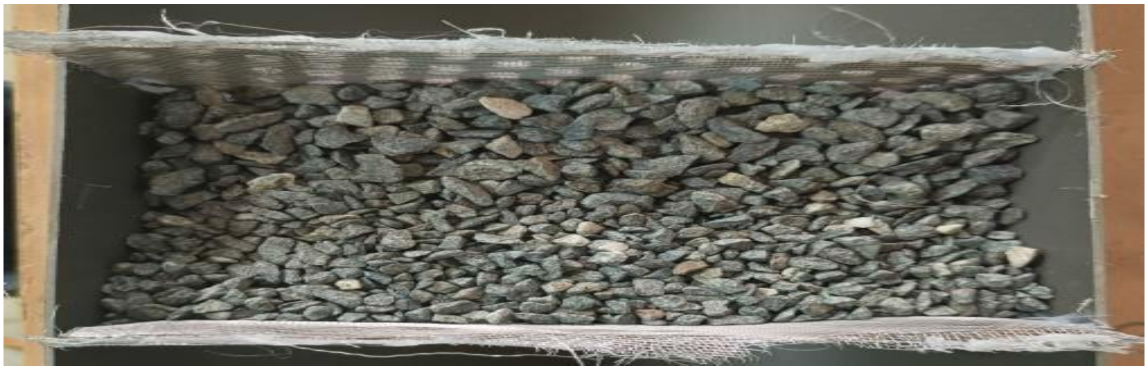

Figure 3.2 : Fine Gravel Media

Figure 3.3 : Coarse Gravel Media

Figure 3.4 : Multimedia Filter (Top View)

Figure 3.5 : Inclined View

3.3 Running the water

Water samples are collected from the Turag River at various points to ensure a representative sample of the river's water quality. The water is introduced at the higher end of the horizontally inclined filter. As the water flows horizontally through the filter with a 5-degree inclination, it first passes through the fine sand layer in Segment 1. This segment captures fine particles and reduces turbidity. Next, the water flows through the fine gravel layer in Segment 2. This segment traps medium-sized particles, further refining the water quality. Finally, the water reaches the medium gravel layer in Segment 3, where larger particles are removed, ensuring the water is effectively filtered before exiting the system. The flow rate is controlled to ensure adequate contact time with each filter media segment. This is achieved using valves or adjustable flow meters to regulate the water flow entering the filter.

3.4 Laboratory Test

Physical Parameters Determination

I. Determination of Total Solids (TS)
II. Total Dissolved Solids(TDS)
III. Total suspended solid (TSS)
IV. Determination of Turbidity
V. Determination of Color

Chemical Parameters Determination

I. Determination of pH
II. Determination of COD

3.5 Bangladesh Environmental Conservation Rules 2023

Table 3.2: Effluent parameter guidelines in ECR 2023

Parameter	unit	ECR'23
pH	-	6.5-8.5
TDS	mg/l	<1000
TSS	mg/l	10
TS	mg/l	00
Color	PtCo	<15
COD	mg/l	4
Turbidity	NTU	10

3.6 Preparation of Apparatus

In order to design and build an effective multimedia filter for river water filtration, the apparatus must first be prepared. To get the filtering performance have to make sure the device is well-designed and built.

3.6.1 pH meter

For accurate measurements of the acidity or alkalinity of water samples, a pH meter is an indispensable instrument in the realm of water quality analysis. Environmental monitoring, industrial procedures, and scientific inquiry all rely on precise pH readings. In order to get a reliable pH reading, the HACH HQ411D pH meter was used.

Figure 3.6: pH Meter

3.6.2 Turbidity Meter

A turbidity meter is a must-have tool for water quality testing since it measures the amount of suspended particles in the water. Soil erosion, sewage runoff, and organic debris are just a few of the variables that can affect turbidity, a key measure of water quality. Aquatic life, disinfection processes, and human health are all negatively impacted by high turbidity levels.. The HACH 2100Q Portable Turbidimeter was used to measure the turbidity of all the samples in this experiment.

Figure 3.7: Turbidity Meter

3.6.3 Spectrophotometer

An analytical tool that can detect the intensity of light absorbed by a sample at various wavelengths, a spectrophotometer is both flexible and exact. For the detection and quantification of organic matter, heavy metals, nutrients, and other chemical substances and pollutants in water, this instrument is indispensable. The HACH DR3900 model was used.

Figure 3.8: Spectrophotometer

3.6.4 COD Reactor Apparatus

The HACH DRB200 Reactor was used for measurements of COD levels in samples. In order to ascertain the concentration of organic compounds in water samples, specialists in environmental and water quality studies employ the Chemical Oxygen Demand (COD) reactor device. The concentration of organic pollutants (COD) is an important metric since it shows how much oxygen may be needed to break them down. When it comes to improving the filtration of river water, the COD reactor is essential for determining how well systems work at purifying water sources like the Turag River from organic pollutants.

Figure 3.9: COD Reactor Apparatus

CHAPTER 4: RESULTS AND DISCUSSION

4.1 General

The final results of the three water run.For better understood they are arranged in a graphical form. The data is then further analyzed to calculate the filter efficiency of the filters that were used.

4.2 Results

Table 4.1:Data of river water before and after the treatment

	Run 1		Run 2		Run 3	
	River Water	Filtered Water	River Water	Filtered Water	River Water	Filtered Water
TDS (mg/L)	124.4	228	143	165	88	177
TSS (mg/L)	5	7	12	13	68	22
TS (mg/L)	129.4	235	155	178	156	199
Turbidity (NTU)	11.7	9.44	12.1	9.48	73	19.7
Color (Co-pt)	55	45	106	91	346	88
pH	8.13	8.51	7.23	7.42	7.55	7.77
COD (mg/L)	20	13	19	16	22	17

4.3 Graphical Analysis

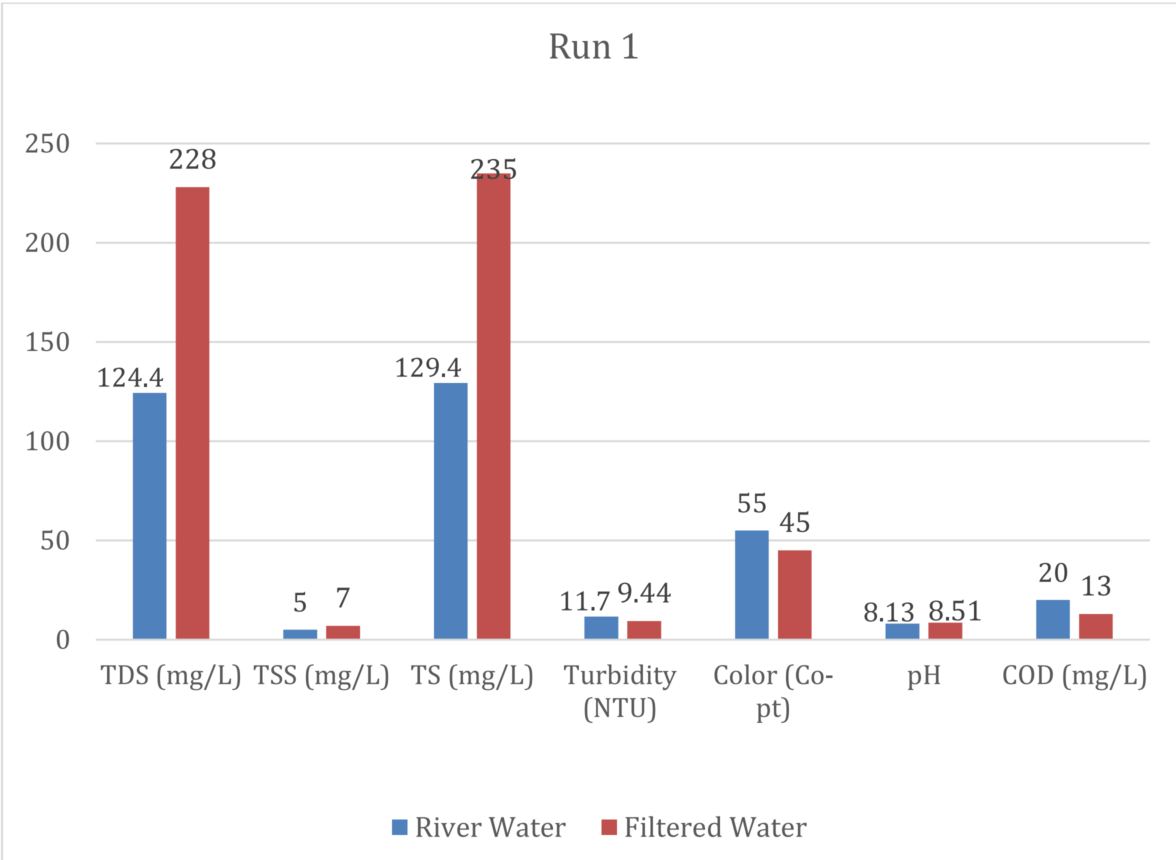

Figure 4.1:Data of river water before and after the treatment for first run of water

The TDS values are 124.4 mg/L for river water and 228 mg/L for filtered water. TSS values are 5 mg/L and 7 mg/L, while TS values are 129.4 mg/L and 235 mg/L for river and filtered water, respectively. Filtration reduced turbidity (11.7 to 9.44 NTU), color (55 to 45 Co-pt), and COD (20 to 13 mg/L), while slightly increasing pH from 8.13 to 8.51. Overall, filtration improved water clarity and reduced organic content.

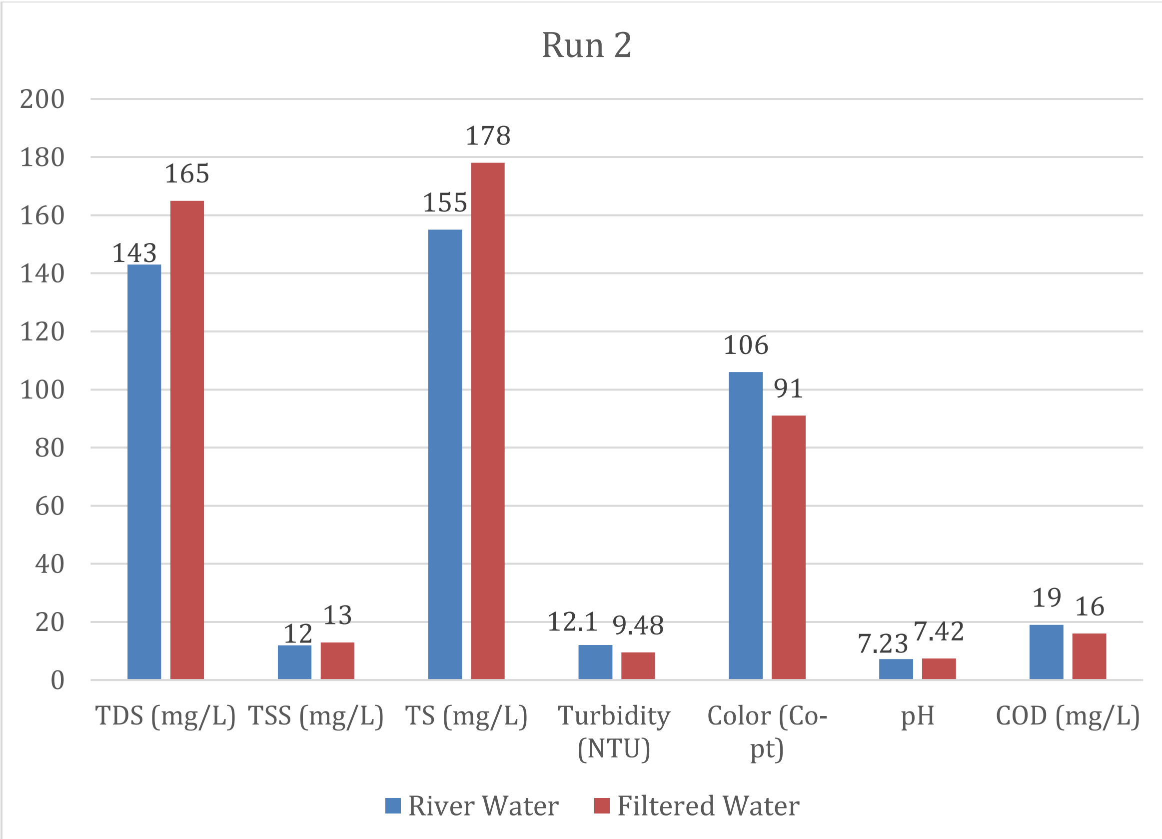

Figure 4.2:Data of river water before and after the treatment for second run of water

The TDS values are 143 mg/L for river water and 165 mg/L for filtered water. TSS values are 12 mg/L and 13 mg/L, while TS values are 155 mg/L and 178 mg/L for river and filtered water, respectively. Filtration reduced turbidity (12.1 to 9.48 NTU), color (106 to 91 Co-pt), and COD (19 to 16 mg/L), while slightly increasing pH from 7.23 to 7.42.

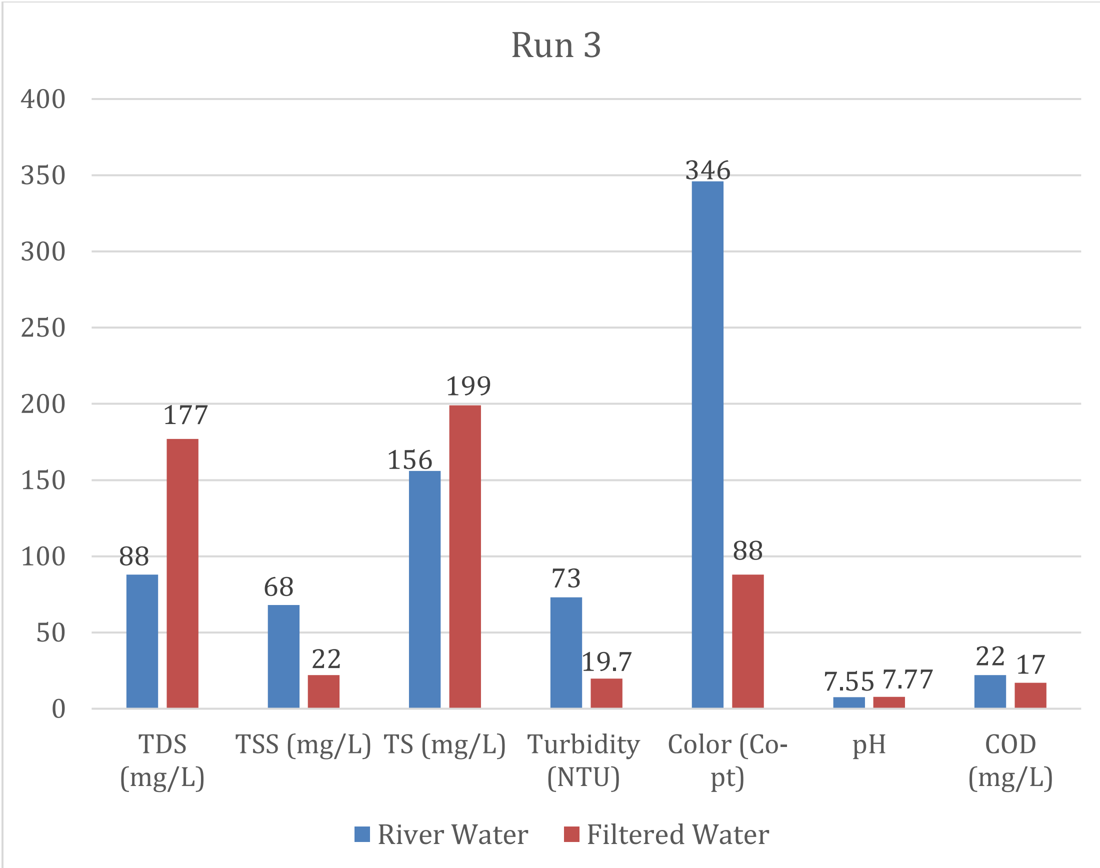

Figure 4.3:Data of river water before and after the treatment for third run of water.

The TDS values are 88 mg/L for river water and 177 mg/L for filtered water. TSS values are 68 mg/L and 22 mg/L, while TS values are 156 mg/L and 199 mg/L for river and filtered water, respectively. Filtration significantly reduced turbidity (73 to 19.7 NTU), color (346 to 88 Co-pt), and COD (22 to 17 mg/L), while slightly increasing pH from 7.55 to 7.77. Overall, filtration improved water clarity and reduced organic content, especially in terms of color and turbidity

4.4.1 Filter Efficiency

Filter Efficiency refers to how well the filter is able to remove a particular parameter. The efficiency has been calculated using the formula:

Efficiency (%) =$[(Initial)−(Final)/(Initial)] *100$

Table 4.2:Filter Efficiency of the filtration for 3 run

	Run 1	Run 2	Run 3
	% of removal/ Improvement	% of removal/ Improvement	% of removal/ Improvement
TDS	-83.27	-15.38	-76.14
TSS	-40	-8.33	-10
TS	-81.6	-14.83	-63.89
Turbidity	19.31	21.65	32.76
Color	18.18	14.15	34.81
pH	-7.4	-2.62	-2.91
COD	35	15.79	22.72

4.4.2 Filter Efficiency (Graphical)

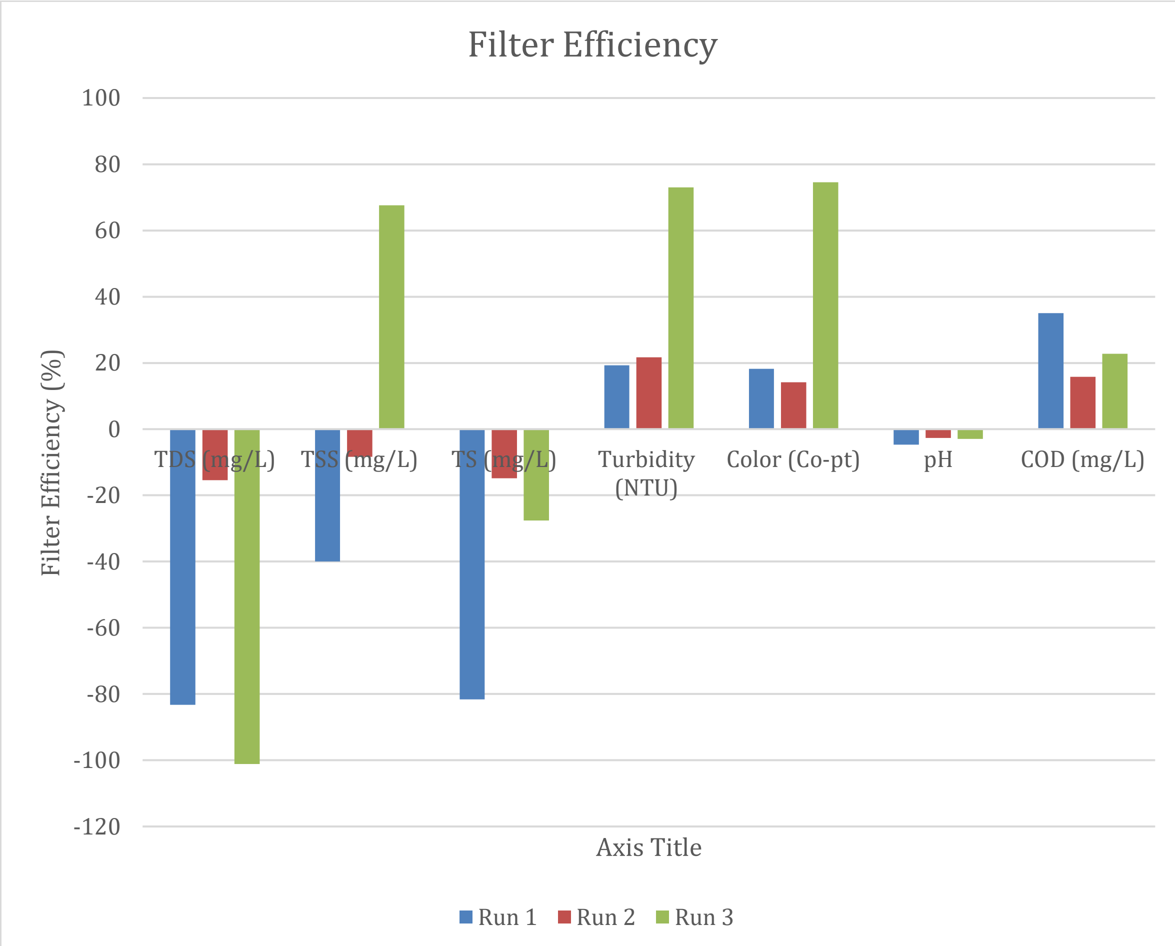

Figure 4.4:Filter Efficiency of the filtration for 3 run

The filter efficiency chart displays the performance across three runs for various water quality parameters. Positive efficiency is observed in reducing turbidity, color, and COD across all runs, with Run 3 showing the highest efficiency for turbidity and color removal. In contrast, negative efficiency is seen for TDS and TS across all runs, indicating an increase in these dissolved solids post-filtration. TSS shows a minor fluctuation, with Run 3 achieving the most significant reduction. Overall, the filtration system effectively improves water clarity and organic load reduction, but it increases dissolved solids.

CHAPTER 5: CONCLUSION & RECOMMENDATION

5.1 Conclusion

The following conclusions can be drawn from this study.

- The use of multimedia filters to enhance the quality of river water is proven in the thesis. The experimental results demonstrate the promise of improved filter designs by showing substantial decreases in turbidity, chemical oxygen demand (COD) and other pollutants. The optimized filter achieved up to a 73% reduction in turbidity.This filter is mainly good for turbidity,color and COD reduction.

- Findings stress the importance of well-designed filters in improving filtering performance. More efficient water treatment solutions may be developed according to the study's framework, which involves modifying multimedia filters' materials and configurations.

5.2 Recommendation

- It is suggested that future research investigate how multimedia filters fare in different environments and with various river water types over extended periods of time. The effect of changing seasons on filter efficiency is one possible example.

- How to improve the removal efficiency of TDS,TSS and TS.

- Can research on filter media's material.

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