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Microplastic Filtration from Waste Water Using Silica

Steffy Maria Simon [1], Aswathy P M [2], Muhsina E K [3], Faiha K [4]

[1] *Assistant Professor, Department of Civil Engineering, IES College of Engineering, Thrissur, Kerala, India*

[2,3,4] *Student, Department of Civil Engineering, IES College of Engineering, Thrissur, Kerala, India*

Email_id: steffymariasimon@iesce.info, aswathyachulal22@gmail.com, muhsinamuhsi19952003@gmail.com, faihasadath8@gmail.com

Abstract

Microplastic contamination in wastewater poses significant environmental and health risks, particularly when treated water is used for irrigation. This study explores the efficiency of silica as a filtration medium for removing microplastics from wastewater and assesses the suitability of the treated water for irrigation. Various silica-based filtration techniques were analyzed, considering factors such as particle size, adsorption capacity, and filtration efficiency. The effectiveness of silica in reducing microplastic concentration was evaluated using microscopic and spectroscopic analyses. Additionally, physicochemical parameters of the treated water, including pH, turbidity, and nutrient content, were assessed to determine its impact on soil and plant health. The results indicate that silica-based filtration can effectively reduce microplastic levels, making the treated water safer for irrigation while maintaining essential nutrients. This study highlights the potential of silica as a cost-effective and sustainable solution for microplastic removal in wastewater treatment.

Keywords: Microplastic filtration, silica, wastewater treatment, irrigation suitability, adsorption, sustainable filtration, environmental protection.

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1. Introduction

Microplastic pollution in wastewater is a significant environmental challenge, especially when treated water is reused for irrigation. These plastic particles, typically smaller than 5 mm, originate from industrial discharge, synthetic textiles, personal care products, and plastic degradation. Once introduced into agricultural systems, microplastics can alter soil properties, hinder plant growth, and potentially enter the food chain. Conventional wastewater treatment processes, including sedimentation, coagulation, and biological treatments, often fail to completely remove microplastics due to their small size and resistance to degradation. Therefore, advanced filtration techniques are necessary to enhance microplastic removal before wastewater is discharged or repurposed for irrigation. This study explores the use of silica as an efficient filtration medium, considering its high porosity, adsorption capacity, and ability to trap fine particles. By evaluating the effectiveness of silica-based filtration in removing microplastics and assessing key water quality parameters, this research aims to determine whether this method provides a sustainable, cost-effective solution for wastewater treatment while ensuring the suitability of treated water for agricultural irrigation.

Figure 1 : Microplastics in waste water

1.1 Objectives of the Study

- To evaluate the efficiency of silica-based filtration in removing microplastics from wastewater.
- To assess the impact of silica filtration on key water quality parameters such as pH, turbidity, and nutrient conten.
- To determine the suitability of treated wastewater for irrigation by analyzing its effects on soil and plant health.

1.2 Scope of the study

- The study investigates silica-based filtration for microplastic removal in wastewater and its suitability for irrigation.
- It examines the impact of silica filtration on water quality, including pH, turbidity, and nutrient retention.
- It evaluates the environmental benefits of reducing microplastic contamination in irrigation water.
- The study explores the feasibility of using silica filtration in large-scale wastewater treatment.

2. Materials and Methods

2.1 Silica

Silica (SiO_2) is a porous, chemically stable, and non-toxic mineral with high adsorption capacity, making it effective for trapping microplastics. Its fine structure, large surface area, and resistance to degradation enhance its suitability for wastewater treatment and safe reuse in irrigation.

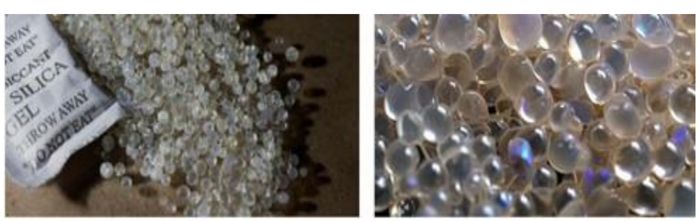

Figure 2 : Silica

2.2 Activated carbon

Activated carbon is a highly porous, chemically stable, and non-toxic material with excellent adsorption capacity, making it effective for removing contaminants from water. Its large surface area and high affinity for organic and inorganic pollutants enhance its suitability for wastewater treatment and purification processes.

Figure 3: Activated Carbon

2.3 Quartz sand 2/4

Quartz sand (2/4 size) is a durable, chemically stable, and highly porous material with excellent filtration properties. Its uniform grain size and high permeability make it effective for removing suspended particles and impurities in wastewater treatment and irrigation systems.

Figure 4 : Quartz Sand 2/4

2.4 Quartz sand 8/16

Quartz sand (8/16 size) is a coarse, durable, and chemically stable filtration material with high permeability. Its larger grain size allows efficient removal of suspended particles while maintaining good water flow, making it ideal for wastewater treatment and irrigation applications.

Figure 5 : Quartz Sand 8/16

2.5 Quartz sand 16/32

Quartz sand (16/32 size) is a medium-to-fine filtration material known for its durability, chemical stability, and high permeability. Its smaller grain size enhances the removal of fine particles while ensuring effective water flow, making it suitable for wastewater treatment and irrigation systems.

Figure 6 : Quartz Sand 16/32

3. Experimental Setup

The experimental setup consists of a column-based filtration system designed to assess the efficiency of silica and other filtration media in removing microplastics from wastewater. The setup includes a coagulation tank, a sedimentation tank, a filtration unit, and a collection system for treated water. Wastewater was sourced from a highly contaminated canal, selected based on a local survey and public opinion, indicating a high likelihood of microplastic contamination. To enhance the study's accuracy, canal water was mixed with laundry wastewater, a known source of microplastic fibers. Since the naturally occurring concentration of microplastics in the sample was low, additional microplastic particles (less than 5 mm) were introduced into 5 liters of water. Initial wastewater parameters, including Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), pH, oil and grease content, were analyzed before filtration. The wastewater was then passed through the filtration unit, which contained layers of silica for microplastic entrapment, activated carbon for adsorption, and quartz sand of varying sizes (2/4, 8/16, and 16/32) for particle removal. The treated water was collected and analyzed for irrigation suitability by measuring parameters such as turbidity, Total Dissolved Solids (TDS), chloride, residual chlorine, and iron content. The results indicated that while the filtration setup effectively reduced microplastic levels, the TDS and turbidity values remained higher than acceptable limits, necessitating further treatment to meet irrigation standards.

While the filtration setup effectively reduced microplastic contamination, the results indicate that additional treatment steps are necessary to optimize water quality for irrigation. Pre-treatment is crucial to remove larger suspended solids, organic matter, and oil and grease, which could otherwise clog the filtration media and reduce its efficiency. Common pre-treatment methods include sedimentation, coagulation, and flocculation, which help in settling larger particles and improving the filtration process. Similarly, post-treatment is essential to further refine the treated water and bring parameters like turbidity and TDS within acceptable limits. Since the filtration process alone was not sufficient to meet irrigation standards, additional treatments such as activated carbon adsorption, ion exchange, reverse osmosis, or aeration may be required to enhance water quality. These steps help in removing residual dissolved solids, fine particles, and any remaining contaminants, ensuring the treated wastewater is safe for agricultural use.

Thus, integrating both pre-treatment and post- treatment with the existing filtration system can significantly improve its overall efficiency, making it a more reliable and sustainable solution for wastewater reuse.

Figure 7 : Prototype

4. Result

Sl No	Parameter	Acceptable Limit	Result	Remark
1	BOD	30mg/1	14	Low level of organic pollution
2	COD	250mg/1	196	Low level of contamination
3	Ph	0-6(acidic) 7 neutral 8_14(alkaline)	7	Neutral
4	TSS	100 mg/l	3.2	Water is clear
5	TDS	500 mg/l	792.33	Presence of excessive salts and minerals
6	Oil and grease	10 mg/l	0.22	Possess no problem to the environment

Table 1: Results of a waste water quality analysis

Table 1 shows the results of a waste water quality analysis and comparing the actual results to the acceptable limits for various parameters. Overall, the water quality is generally good, except for the high TDS level, which may require further investigation and mitigation measures.

The water quality analysis reveals that most parameters are within acceptable limits, indicating relatively good water quality. The low levels of BOD, COD, and oil and grease suggest minimal organic and inorganic pollution. The pH level is neutral, and the TSS level indicates clear water. However, the TDS level exceeds the acceptable limit, suggesting the presence of excessive salts and minerals, which may require further investigation and the mitigation measures. Overall, while the water quality is generally satisfactory, attention is needed to address the high TDS level to ensure the water is safe for consumption or other uses.

Sl.No	Parameter	Acceptable Limit	Result	Remark
1	Turbidity	1	10.2 NTU	High level of suspended solids
2	Electrical Conductivity	-	1036	High level of dissolved solids
3	Acidity	-	BDL 191	Non corrosive Moderate
4	Alkalidity	200 mg/1	16.02mg/l	buffer capacity
5	Calcium	75 mg/1	17.01mg/l	Soft water
6	Magnesium	35 mg/1	120mg/l	Suitable for irrigation purpose
7	Chloride	250	0.89	Suitable for irrigation purpose
8	Iron	1	Nil	Cause unpleasant odour, taste etc
9	Residual Chlorine	-	BDL	Health risk
10	Nitrate	45 mg/1	37.88mg/l	Low
11	Sulphate	250 mg/1	0.48mg/l	Suitable for Irrigation purpose
12	Flouride	1	-	Safe

Table 2: Results of a waste water quality analysis

The treated water test results indicate that the water sample has some quality issues that need to be addressed before it can be safely reused for agricultural purposes. Specifically, the high turbidity (10.2 NTU) and total dissolved solids (1200 mg/L) may pose problems for irrigation systems and soil health. Additionally, the soft water with low calcium levels (75 mg/L) may require supplemental calcium to support crop growth. However, the moderate alkalinity and suitable levels of magnesium, chloride, and sulfate are positive factors. To improve the water quality, treatment technologies such as sedimentation, filtration, and nutrient removal may be necessary.

5. Conclusions

- Effective Microplastic Removal – The filtration setup efficiently captures microplastics using silica, activated carbon, and quartz sand, reducing contamination levels in wastewater.

- Eco-Friendly Solution – The materials used in the filtration system are naturally available, non-toxic, and do not introduce harmful chemicals into the environment, making it a sustainable option.
- Cost-Effective Approach – Compared to advanced treatment technologies like membrane filtration or reverse osmosis, this method offers a more affordable solution for wastewater treatment without requiring high operational costs.
- Potential for Wastewater Reuse – By improving water quality, the system enables the safe reuse of treated wastewater for irrigation, promoting water conservation and reducing dependence on freshwater sources.
- Scalable and Adaptable – The filtration setup can be easily integrated into existing wastewater treatment plants or modified based on specific water quality needs, making it a practical solution for various applications.

6. References

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