

Smart Adsorption Greywater System

Sreya M¹, Dr. M. Makesh Kumar², Vigneshwaran S³, Awanish Kumar Sinha⁴, Dr. M. Laxmi Deepak Bhatlu⁵

¹UG Scholar, Department of Chemical Engineering, KPR Institute of Engineering & Technology, Coimbatore, Tamilnadu, India.

²Associate professor, Department. of Mechanical Engineering, KPR Institute of Engineering & Technology, Coimbatore, Tamilnadu, India.

³UG Scholar, Department of Mechatronics Engineering, KPR Institute of Engineering & Technology, Coimbatore, Tamilnadu, India.

⁴UG Scholar, Department of Civil Engineering, KPR Institute of Engineering & Technology, Coimbatore, Tamilnadu, India.

⁵Assistant professor(III), Department of Chemical Engineering, KPR Institute of Engineering & Technology, Coimbatore, Tamilnadu, India.

Emails: sreyamanjunath291@gmail.com¹, makeshmech@gmail.com², vigneshwaran2020s@gmail.com³, raj555awanish@gmail.com⁴, dbhatlu.rs.che@iitbhu.ac.in⁵

Abstract

Water scarcity is a rising issue world-wide that has been accelerated by population increase, rapid urbanization, and unavailability of fresh water, and therefore wastewater reuse is a key factor for proper water management. Laundry wastewater constitutes a substantial proportion of household wastewaters and can be reused safely for other uses following proper treatment. This study focuses on the Smart Adsorption Greywater System that can treat and recycle laundry wastewater at a household treatment. It employs a filtration and adsorption process using natural and low-cost material such as cotton, gravel, sand, micro-filter paper, and natural adsorbents like activated charcoal, activated Mahogany powder for the removal of suspended solids, clarification, adsorption of color and odor, and removal of detergents and dissolved organics, reduction of TDS, Turbidity, Conductivity, and pH. A disinfection stage is also provided at the end for ensuring the suitability of the treated water for use as non-potable water for irrigation practices, flushing of toilets, and other cleaning purposes. The project proves the ability for a low-cost water recycling conservation technology.

Keywords: Adsorption system; Greywater treatment; Laundry wastewater; Natural filter media; Non-potable water reuse.

1. Introduction

The pressure on freshwater sources, caused due to rapid growth of population and urbanization, is increasing. These conditions, in turn, are made worse because of the impacts of global warming. A major share of freshwater used in households is consumed in various daily tasks such as bathing, washing dishes, and clothes washing. The composition of the greywater generated from a laundry includes about 99% water, while the rest contains a mass percentage of suspended solids within the range of 60-330 mg/L, surfactants or detergents (10 - 40 mg/L), oil and greases (20-100 mg/L), dissolved organic compounds with COD of 400-1200 mg/L, in addition to lint fibers, phosphates, and traces of microplastics.

Clothes washing greywater contains a large quantity of salts, detergents, suspended materials, lint, and microfibers that do not make it amenable to reuse. In many households in urban and semi-urban areas, water scarcity has increasingly been to increase in cost. According to Yadav et al. (2024), the reduction in turbidity, odor, organic matter, and dissolved substances verified its efficacy as a treatment material in a home setting. [1]. In such situations, treatment of laundry water for reuse has been shown to provide an urgent means of decreasing water usage at household levels. However, for years, treatment of greywater has been expensive, energy intensive, and complicated for household treatment. The design and

development of the Smart Adsorption Greywater System and its use in the treatment of laundry wastewater are the focus of this study. Zaher M. Yaseen et al. (2019) research investigated treating laundry grey water using a combined naturally-based filtration and adsorption medium of sand, biochar, and teff straw [2]. Rather than considering wastewater treatment from multiple sources, the treatment of laundry wastewater through this system allows for better control of the wastewater and, therefore, better treatment. The wastewater treatment process involves a mix of natural materials for filtration and adsorption, such as gravel, sand, cotton, activated carbon, and adsorbed plants. This technology is based on the gravitation flow process and does not require any electrical energy, and because of this, it is considered to be very economical, environmentally friendly, and safe to be used at home domestically. Quispe et al. in 2023 gives the design of smart adsorption greywater systems, wherein optimized filter configurations improve treatment efficiency for the reutilization of household wastewater [3]. It is easy to use because of its ease of use design, and this treated water can be reused for other practices such as gardening, thereby conserving water and preventing environmental pollution.

2. Materials and Methods

The grey water treatment system consists of a sequential arrangement of the pretreatment, filtration, adsorption, monitoring, and storage units designed for effective household laundry wastewater reuse. The multilayer column design, controlled flow rate, and enough contact time as very important parameters in enhancing the treatment performance [4]. The grey water from laundering activities enters the system through a PVC inlet equipped with a stainless steel or nylon mesh pre-filter, which removes the coarse impurities like lint, hair, cloth fibers, and soap residues and thus protects the downstream components from clogging.

2.1. Grey Water Inlet and Mesh pre-filter

The grey water generated as a consequence of laundry activities is then brought in through a PVC inlet with a mesh screen. This assists in eliminating lint, hair, and soap residue to prevent jamming in the following equipment.

2.2. Settling Tank

The Settling tank slow down the movement of greywater. Consequently, heavy components in greywater fall by the action of gravity. Additionally, it provides consistent flow to a filtration column and adjusts for variations in a washing machine flowrate.



Figure 1 Laundry Greywater

2.3. Multi-Layer Filtration and Adsorption Column

The materials employed for filtration are as follows: from top to the bottom of the column, the materials are: sand, activated carbon, mahogany activated leaf powder, a second layer of activated carbon, stones, and wool. The filter performance was strongly influenced by the size of the filter media, layering arrangement, and flow rate [5]. Hence, a filtration process capable of removing suspended particulates, organic materials, and salts simultaneously is provided. Therefore, eliminate suspended impurities, detergents, surfactants, aroma, and dissolved impurities. Kirtidhvaj et al. (2023) studied plant leaves ash as an innovative, low-cost adsorbent in treating wastewater. Such as ash, derived from commonly available plant leaves, was found to possess a structure of pores and active surface sites [6].

2.3.1. Preparation of Activated Mahogany powder

Activated mahogany powder was prepared by washing the fresh leaves, oven drying the leaves, fine grinding using mortar and sieving using 170-micron size, chemical activation with dilute HCl, carbonization at 500°C, neutralization with 0.1 N NaOH, and finally drying to obtain a stable natural adsorbent.

2.4. Flow Control System and Valves

The use of flow control valves helps to control the rate of the flow and ensures that there is an adequate level of contact time in the filter medium. They also provide capabilities for backwashing and recirculation, which are useful for system cleaning and optimization.

2.5. Water Quality Monitoring Section

pH, TDS, turbidity, and conductivity measurements are conducted by water quality sensors and meters before and after treatment. This helps determining the efficiency of the system as well as whether the standards of non-potable water re-use are met.

2.6. Treated Water Collection and Storage Tank

This greywater is then stored in an enclosed tank, primarily to prevent the water from being contaminated. Grey water can now be stored and reused in non-potable purposes, which may include gardening, flushing toilets, or floor cleaning.

2.7. Proposed Methodology

The greywater generated from the domestic laundry activities was collected and analyzed for critical physicochemical parameters like pH, total dissolved solids (TDS), turbidity, electrical conductivity, color, odor, and temperature. The way the samples were taken and stored is important because we know that the quality of greywater gets bad quickly. Sochacki and others did a study in 2024 on using biochar to clean up greywater. They looked at how to remove things like soap, dirt and bad stuff from the water [7]. A small system was made with things like sand activated carbon and special charcoal. This system had layers with different materials like leaves, cotton and stones. Figure 2, shows how the system was designed. The materials were put in layers to see how well the system works. Some people like Vuppaladadiyam and others did a study in 2024 that lasted one year. They looked at how a greywater treatment system worked in a home. They used things like cloth, special textiles and cotton to clean the water. The results were good. The system removed all of the bad stuff from the water. It removed than 96 percent of the cloudiness 97.5 percent of the solid bits 82 percent of the bad organic stuff and 75 percent of the chemical bad stuff. It also removed a lot of the bacteria, like E. Coli, from the greywater [8].

Experimental studies were conducted in the laboratory using different flow rates to evaluate system performance and treated water parameters are monitored. Paul et al. (2020) found that activated carbon showed high effectiveness in reducing suspended solids, organics, and heavy metals due to its large impact on surface area and porosity [9].

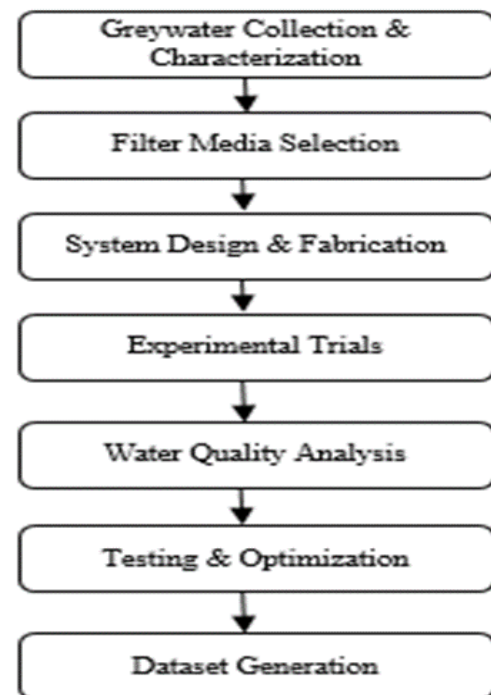


Figure 2 Proposed Methodology

3. Results and Discussion

The greywater employed in the study is obtained from the outlet of the washing machine. It is a constant and easily accessible domestic water. The type of laundry greywater tends to contain large proportions of detergent, surfactant agents, salts, and suspended materials such as lint, fibers, particulates, and micro-particles of fabric. Preliminary water quality analysis gave the following results: pH of 7.71, turbidity of 91 NTU, TDS of 5450 ppm, and conductivity of 8.4 mS/cm, indicating a very high level of pollution; therefore, the water is unfit for domestic and irrigational uses. The researchers, Danbature et al. (2024) Looked into producing activated carbon from waste mahogany fruit shells. They added TiO₂ to it. This was to make it useful for treating water. The findings revealed that the

mahogany-derived activated carbon possessed high porosity, an increased surface area, and increased chemical reactivity, which enabled it to adsorb cadmium and arsenic ions successfully at very low concentrations [10]. For the above purpose, a transparent and multi-layered filter column design has been conceptualized that helps in the sequential treatment, flow rate control, and observation of the filtered water samples as may be required.



Figure 3 Filtration Column

The flow rate and layer thickness were optimized to avoid clogging of the flow path, along with ensuring reproducibility. In this work, water samples of treated water were collected at regular time intervals till steady-state conditions were obtained. The water has lot of stuff in it but then it got cleaned up. The amount of stuff called TDS went down from 5450 parts per million to 4500 parts per million which is about 18 percent less. The water also became less conductive going from 8.4 to 6.7 millisiemens per centimeter. After treatment, the water was clearer because the turbidity was reduced. The pH of the water remained same. This shows that using a multi-step filtration process really works. We took water samples over a period of 10 days. Each water sample was treated in a way with three main things being changed: how fast the water flowed how tall the filtration column was and what the greywater was like. The cleaned water is not good enough to drink. There are other use like gardening and flushing toilets. We want to keep the TDS between 1000 and 1500 parts per million for these uses. We got results from five water samples, which are shown in the tables. We did experiments with laundry greywater and the TDS and turbidity

went down differently for each water sample. The reduction of TDS and turbidity will be different for each water sample because each laundry greywater is unique. We used the step natural filtration approach, for each water sample and it worked well for reducing the TDS and turbidity in the water samples.

Table 1 Sample 1

S.No	Time (Min)	After Treatment		
		pH	TDS (ppm)	Conductivity (mS/cm)
1.	15	7.2	2260	4.31
2.	30	7.1	2780	4.45
3.	45	7.0	2998	5.68
4.	60	7.0	3520	5.88
5.	75	7.0	3805	6.50
6.	90	7.1	4287	6.78
7.	105	7.2	4887	7.25
8.	120	7.5	5200	7.80

Table 2 Sample 2

S.no	Time (Min)	After Treatment		
		pH	TDS (ppm)	Conductivity (mS/cm)
1.	15	7.9	1260	2.31
2.	30	7.10	1380	2.64
3.	45	8.2	1725	3.57
4.	60	8.4	2200	3.82
5.	75	8.6	2458	3.96
6.	90	8.7	2766	4.32
7.	105	8.8	3421	4.69
8.	120	9.0	3736	5.97

The water treatment process made the water quality a lot better in the 30 minutes of filtration. Examining Table 2, it was seen that Total Dissolved Solids or TDS went down fast from 3920 parts per million to 1260 parts per million in just 15 minutes. This means the water treatment process was very good at

removing the dissolved salts and detergent residues from the water. The water's conductivity also went down from 6.9 millisiemens per centimeter to 2.31 millisiemens per centimeter which shows that the treatment process was effective in reducing the pollutants in the water. The pH of the water changed from a high alkaline value of 11.8 to a value that is close to neutral. The water flow rate was two milliliters per minute and the height of each layer of the filter bed was about 10 centimeters. If we look at Table 1, we can see that the TDS went down from 5450 parts per million to 2260 parts per million in 15 minutes of filtration. The water treatment process was really good, at reducing the Total Dissolved Solids in the water.

Table 3 Sample 3

S.No	TIME (Min)	After Treatment		
		pH	TDS (ppm)	Conductivity (mS/cm)
1.	15	7.1	980	1.52
2.	30	7.0	1025	1.89
3.	45	7.2	1150	2.01
4.	60	7.3	1280	2.18
5.	75	7.4	1395	2.36
6.	90	7.5	1510	2.61
7.	105	7.5	1650	2.75
8.	120	7.7	1785	2.84

The results of TABLE 3, are really interesting especially what happens in the 15 to 30 minutes. During this time the amount of stuff in the water called TDS goes down a lot from 2360 ppm to 980 ppm. This demonstrates the filter's functionality at first. The water's conductivity also decreases, from 3.37 mS/cm to 1.52 mS/cm which means the filter is doing a job of removing bad things like dirt and soap. We tested the water in the laboratory using tools. The pH of the water does not change much it stays about the same. The big problem is the high amount of TDS in the water. Using mahogany charcoal to treat the water helps a lot it makes the water look and smell better. It also reduces the TDS. This is important for

uses where the water does not need to be drinkable. These results can help us design a system for cleaning the water. The filtration results of TABLE 3 are very useful, for this.

Table 4 Sample 4

S.No	TIME (Min)	After Treatment		
		pH	TDS (ppm)	Conductivity (mS/cm)
1.	15	7.5	1480	2.64
2.	30	7.6	1602	3.85
3.	45	7.7	2670	4.20
4.	60	7.9	3756	5.68
5.	75	8.4	3987	6.87
6.	90	8.9	4120	7.26
7.	105	10.2	5890	8.2
8.	120	10.5	6118	8.6

The treatment process made a difference. In the 15 minutes as shown in Table 4, the treatment process made a big difference. The TDS treatment process went down a lot from 6120 ppm to 1480 ppm. This shows that the treatment process removed a lot of salts and detergent residues. The conductivity of the water also went down from 5.4 mS/cm, to 2.10 mS/cm.



Figure 4 pH meter

This means the treatment process removed a lot of pollutants. The pH of the water changed from an

alkaline at 9.2 to a more neutral range of 7.8 to 8.1. This happened in the stages of the treatment process. It shows that the filter media did a job of buffering the water. The treatment process did a job of making the water cleaner. Figure 4., shows the testing of the laundry greywater at every 15 minutes of the experiment. The laundry greywater is cloudy in color since it contains a lot of it like turbidity and total dissolved solids, which are also known as TDS and other tiny particles that make the laundry greywater look cloudy. The laundry greywater testing is done to see how the pH of the greywater changes, over time.

Table 5 Sample 5

S.No	TIME (Min)	After Treatment		
		pH	TDS (ppm)	Conductivity (mS/cm)
1.	15	7.8	1680	2.10
2.	30	7.5	1895	2.36
3.	45	7.9	2240	2.84
4.	60	8.1	2590	3.20
5.	75	8.3	2915	3.58
6.	90	8.4	3270	3.96
7.	105	8.6	3625	4.41
8.	120	8.7	3950	4.88

Table 5 shows that the treated greywater is of higher quality. The water has time to go through the filtration materials, which explains this. The materials used for filtering are thicker. They come into contact with the water more frequently. This aids in clearing the water of everything. The water gets cleaner because it has time to react with the filtration materials. This means that the TDS and conductivity and pH values get lower and lower over the 2 hours that the water is being treated. The pH values and all that they go down in a way. The deeper filtration materials also help to get rid of the leftover detergent and the tiny bits of dirt that are floating around in the water. The dissolved salts are eliminated. As a result, the final water is extremely pure. It doesn't really alter. The greywater is cleaner and more stable after it has been treated.

Conclusion

This study did a job of developing and testing a system to treat greywater using adsorption. The system was checked by looking at things like the amount of dissolved solids, how conductive the water was how cloudy it was and the pH level. The purpose of all this was to assess the system's feasibility for residential use. The system was tested in ways over ten days. The water quality got a lot better quickly within thirty to forty-five minutes. This happened because the system used a combination of filtering, adsorption and ion exchange. The good thing about the materials used in the system is that they are not harmful to the environment. The materials used for adsorption really helped make the system sustainable. Therefore, the technology they developed to treat greywater so it may be used again is excellent.

Acknowledgements

The authors sincerely thank Dr. K. P. Ramasamy (Chairman), Ms. Gayathri Anandakrishnan (Secretary), Dr. A. M. Natarajan (Chief Executive), Dr. R. Devi Priya (Principal), and Dr. G. Anusha (Vice Principal) at KPR Institute of Engineering and Technology for their unwavering guidance and support. A special thanks goes to Dr. M. Makesh Kumar, Project Supervisor, Department of Mechanical Engineering. Throughout the research process, their advice and knowledge were really helpful.

References

- [1]. Yadav, S., Singh, R., & Verma, P. (2024). Household Wastewater Treatment Using Activated Charcoal: An Effective and Sustainable Approach. *International Journal of Environmental Science and Technology*, 21(3), 1452–1461. <https://doi.org/10.1000/Ijest.2024.1452>
- [2]. Yaseen, Z. M., Al-Jawad, S. M., Al-Shammari, A. A., Al-Ansari, N., & Laue, J. (2019). Laundry Wastewater Treatment Using a Combination of Sand Filter, Bio-Char and Teff Straw Media. *Scientific Reports*, 9(1), 18709. Nature Publishing Group. <https://doi.org/10.1038/S41598-019-54888-3>
- [3]. Bautista Quispe, J. I. B., Hardin, R., Nakatsu, C. H., & Sutherland, J. W. (2023).

- Optimisation of Biochar Filter For Handwashing Wastewater Treatment and Potential Treated Water Reuse for Handwashing. *Journal of Water Process Engineering*, 54,104001. Elsevier. <https://doi.org/10.1016/J.Jwpe.2023.104001>
- [4]. Bautista Quispe, J. I., Mohanty, S., & Dash, R. R. (2022). Use of BiocharBased Column Filtration Systems for Greywater Treatment: A Systematic Literature Review. *Journal of Water Process Engineering*, 47, 102725. Elsevier. <https://doi.org/10.1016/J.Jwpe.2022.102725>
- [5]. Shaikh, I. N., & Ahammed, M. M. (2022). Granular Media Filtration for OnSite Treatment of Greywater: A Review. *Water Science & Technology*, 85(2), 439–456. IWA Publishing. <https://doi.org/10.2166/Wst.2021.505>
- [6]. Kirtidhvaj, J. G., Tippat, S. K., & Gudadhe, S. K. (2023). Wastewater Treatment Using Plant Leaves Ash. *Environmental Technology & Innovation*, 30, 103123. Elsevier. <https://doi.org/10.1016/J.Eti.2023.103123>
- [7]. Sochacki, A., Kozyatnyk, I., & Józwiak, A. (2024). Adsorption of common greywater pollutants and nutrients by engineered biochar. *Environmental Pollution*, 330, 122112. Elsevier. <https://doi.org/10.1016/j.envpol.2023.122112>
- [8]. Vuppaladadiyam, R., Sharma, P., & Patel, A. (2024). Performance of an Integrated Household Greywater Treatment System for Water Optimization and Reuse. *Applied Water Science*, 14, 23. Springer. <https://doi.org/10.1007/S13201-024-01987-2>
- [9]. Paul, A. (2020). Water Treatment Using Chemically Activated Charcoal. *Materials Today: Proceedings*, 33(2), 1543–1549. Elsevier. <https://doi.org/10.1016/J.Matpr.2020.03.712>
- [10]. Danbature, W. L., Pindiga, N. Y., & Ibrahim, A. M. (2024). Synthesis and Characterization of Activated Carbon from Mahogany Fruit Shell (*Khaya Senegalensis*) Impregnated with TiO_2 Used in the Adsorption of Cadmium and Arsenic. *Journal of Environmental Chemical Engineering*, 12(1), 110452. Elsevier. <https://doi.org/10.1016/J.Jece.2024.110452>