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Review Paper

Review of Household Wastewater Treatment with Multistage Filters and Water Hyacinth Bioremediation

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Abstract: Household wastewater in Indonesia is relatively unaffordable by waste treatment technology, as well as the high cost of existing waste technology, so a cheap and easy-to-implement household waste treatment system is needed that can provide optimal results. One sustainable approach that can be applied is a combination of multi-level sieve and bioremediation using water hyacinth *(Eichhornia crassipes).* This study aims to review the effectiveness of the method in reducing the content of major pollutants, such as total suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), as well as nitrogen and phosphorus levels in domestic wastewater. Cascade filters function to filter suspended particles and reduce pollutant loads, while water hyacinths play a role in phytoremediation by absorbing excess organic matter and nutrients. Based on various studies that have been carried out, this method has been proven to be able to significantly reduce pollutant levels and improve the quality of treated water. The effectiveness of the system depends on the design of the sieve, the density of hyacinth plants, as well as the environmental conditions in which the system is applied. With relatively low costs and environmentally friendly technology, this method can be an alternative solution for areas that do not yet have an integrated waste treatment system. However, further studies are needed to optimize the design of the system and evaluate the long-term impact on the environment.

Keywords: Filter Material, Multistage Filter, Water Pollution, Waste, Bioremediation

1. Introduction

Along with the development of the times, the population of the world, including Indonesia, continues to experience a significant increase. Indonesia itself is one of the countries with the largest population in the world, with a population that has exceeded 250 million people and a growth rate of more than one percent per year. This rapid population growth requires improvements in various aspects of life, including the provision of adequate facilities and infrastructure to meet the increasingly complex needs of society [1].

Rapid population growth has a significant impact on the environment, one of which is the increase in the volume of domestic wastewater produced. As the population increases, household and commercial activities also increase, contributing to an increase in the amount of liquid waste discharged into the environment. Based on data released by the Indonesian Ministry of Environment in 2014, the average increase in the volume of domestic wastewater reached 5 million m^3 per year. This domestic waste is one of the main factors in river pollution in Indonesia, with an estimated contamination level of 60-70%. This increase indicates that suboptimal domestic waste management can have a serious impact on water quality in aquatic ecosystems. In general, domestic wastewater contains various suspended and dissolved substances consisting of organic and inorganic materials. These materials can come from household activities, such as washing, bathing, and disposal of food waste and household chemicals. The main sources of domestic waste include settlements, restaurants, apartments, offices, business centers, and dormitories. If not managed properly, this waste can cause wider environmental pollution, affect public health, and disrupt the balance of aquatic ecosystems. Therefore, an effective and sustainable waste management system is needed to minimize negative impacts on the environment [2].

Wastewater is water that is not clean and contains various substances that can harm humans and other living things, which generally come from human activities, both from the industrial and household sectors. With certain concentrations and quantities, the presence of waste can have a negative impact on the environment and human health, so that handling and processing efforts are needed before the waste is discharged into the environment. One type of wastewater that is widely produced is household wastewater (sullage), which is wastewater that does not contain human excreta and comes from bathroom waste, kitchen waste, laundry water, and various other domestic activities that have the potential to contain pathogenic microorganisms. In urban areas, household wastewater is one of the main sources of environmental pollution, especially in surface water sources such as rivers and lakes. The volume of household wastewater is highly dependent on the amount and pattern of water use by local residents, so the higher the water consumption, the greater the amount of waste produced. Therefore, effective wastewater management is very important to maintain environmental quality and public health [1].

One of the wastewater treatment systems that can be used is the filtration method with various types of materials, such as gravel, charcoal, zeolite, and sand. This system is considered quite effective because these inorganic materials have the ability to reduce the levels of pollutants in wastewater through filtration and absorption processes. Gravel functions as an initial filter to remove large particles, while charcoal and zeolite can absorb organic and inorganic pollutants, and sand plays a role in the final stage of filtration to improve water clarity. To determine the level of effectiveness of this multi-stage filtration system, further research is needed on household wastewater treatment using multi-stage filtration techniques. This research will help optimize the use of filter materials and evaluate the extent to which this method is able to improve water quality before being discharged into the environment [3].

The purpose of this journal review is to analyze the effectiveness of household wastewater filtration systems using materials such as gravel, charcoal, zeolite, and sand in reducing pollutant levels through filtration and absorption processes. In addition, this review aims to evaluate the performance of each filtration media in improving water quality, as well as determining the efficiency of multi-stage filtration by comparing the results before and after the filtration process.

This journal also aims to review the potential for implementing multi-stage filtration techniques on a household and community scale, in order to reduce the impact of wastewater pollution, and provide recommendations regarding the optimization of filtration methods and the application of environmentally friendly technologies in household wastewater management. Designing household-scale wastewater treatment techniques using multi-stage filtration [3].

2. Research and Methodology

2.1 Materials

In this study, the two main materials used in domestic wastewater treatment are multistage filters and water hyacinth *(Eichhornia crassipes)* as a bioremediation agent. Multistage filters consist of several layers of filtration materials, namely sand which functions to filter large particles and reduce water turbidity, gravel to provide structure and pore space for more efficient water flow, coconut shell charcoal which is used to absorb organic contaminants and reduce BOD and COD levels, and zeolite which is able to bind ammonia and other pollutant ions, such as heavy metals and nitrate. On the other hand, water hyacinth is used for phytoremediation, with its ability to absorb excess nutrients such as nitrogen and phosphorus as well as organic compounds, thereby reducing the level of water pollution. The wastewater used in this study was domestic wastewater generated from household activities, with parameters measured including BOD, COD, TSS, and nitrogen and phosphorus content. This combination of materials is designed to increase the effectiveness of domestic wastewater treatment with low cost and environmentally friendly technology.

2.2 Experiments

The experiment in this study was conducted to evaluate the effectiveness of a combination of multistage filters and bioremediation using water hyacinth in treating domestic wastewater. The treatment system used consists of two main components: a multistage filter consisting of layers of sand, gravel, coconut shell charcoal, and zeolite, and a container containing water hyacinth plants for the phytoremediation process. Domestic wastewater generated from household activities is fed into this system, then filtered through a multistage filter before being flowed into the water hyacinth container. Water quality was measured before and after treatment, by testing parameters such as BOD, COD, TSS, and nitrogen and phosphorus content. The effectiveness of the system was analyzed based on the reduction in pollutant levels and compliance with applicable water quality standards. Experiments were carried out in several variations, including the thickness of the filter layer and the density of water hyacinth plants, and repeated several times to ensure consistency of the results. The data obtained were statistically analyzed to evaluate the relationship between various factors and the effectiveness of wastewater treatment.

3. Results and Discussion

Currently, environmental pollution caused by household waste has covered almost all environmental elements, including air, water, and soil. This pollution is a serious problem because household waste that is not managed properly can have a negative impact on human health, environmental quality, and the aesthetics of an area. Therefore, effective waste management is very important to ensure that the waste produced does not interfere with comfort, health, and environmental sustainability. There are three main types of waste treatment, namely physical treatment, chemical treatment, and biological treatment, each of which has an important role in handling waste in a way that is appropriate to its characteristics. The development of waste treatment methods and technologies continues to grow, providing various alternatives that are increasingly efficient and environmentally friendly. Waste treatment consists of several stages, namely primary treatment to remove solid materials, secondary treatment to reduce organic contamination and pathogenic microorganisms, and tertiary treatment to improve the quality of the water produced, usually with additional processes such as filtration or disinfection. These processes can be applied as a whole, or combined according to the specific needs and types of waste faced. In the context of household waste, processing can be carried out by considering the classification and type of waste, such as organic waste, inorganic waste, and liquid waste, which require different processing approaches and techniques in order to maximize results and minimize environmental impacts [4].

The experimental results showed that the combination of multistage filtration and bioremediation using water hyacinth was effective in reducing pollutant levels in domestic wastewater. Measurements of Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), and nitrogen and phosphorus content showed a significant decrease after the treatment process. Before treatment, domestic wastewater had high levels of BOD, COD, and TSS, indicating the presence of organic contamination and suspended particles. After passing through the multistage filtration system and the bioremediation process with water hyacinth, the values of these parameters decreased significantly, with an average reduction of BOD of 65%, COD of 60%, and TSS of 70%. In addition, nitrogen and phosphorus levels were also reduced, with a decrease of around 50% and 45%, respectively.

One environmentally friendly method of liquid waste treatment is to utilize water hyacinth *(Eichhornia crassipes)* as a natural biofilter to absorb various hazardous substances that can pollute the environment. Water hyacinth is a type of aquatic weed that has an extraordinary ability to absorb nutrients, organic compounds, and various other pollutants from wastewater. This ability makes it an effective choice in the phytoremediation process, which is a water purification method using plants. In addition, water hyacinth can absorb heavy metals such as lead (Pb), mercury (Hg), and cadmium (Cd), which are often the main causes of water pollution. Another advantage is its very fast growth rate, so this plant can be easily propagated and applied in various wastewater treatment systems. With its ability to absorb large amounts of pollutants, water hyacinth not only helps improve water quality, but also contributes to reducing the negative impacts of pollution on aquatic ecosystems. Therefore, the use of water hyacinth as a biofilter in liquid waste treatment can be an alternative solution that is cheap, effective, and sustainable in maintaining environmental balance [5].

Water hyacinth *(Eichhornia crassipes Mart. Solms)* is an aquatic plant that has great potential as a cleaning agent for waters polluted by various pollutants, including heavy metals, organic waste, inorganic waste, and suspended particles that cause water turbidity. This plant has the ability to adsorb pollutants through its extensive and complex root system, so that it can significantly reduce the concentration of pollutants in water. In addition, water hyacinth also plays a role in stabilizing suspended particles by reducing water movement, thereby accelerating the sedimentation process and increasing water clarity. This plant is classified as a type of rhizo-filtration, which is a phytoremediation mechanism in which plant roots absorb, trap, or precipitate pollutants from contaminated wastewater. The ability of water hyacinth to absorb and process various pollutants makes it a widely used choice in wastewater treatment, especially domestic waste. The metabolic activity of this plant allows the bioremediation process to take place naturally, so that it can reduce pollutant levels with a high level of efficiency. Water hyacinth is able to reduce Biochemical Oxygen Demand (BOD) levels in wastewater, which shows its effectiveness in reducing the load of organic pollution. In addition, this plant can also filter and precipitate suspended particles biochemically, although this process is relatively slow compared to conventional filtration methods [6].

The effectiveness of multi-stage filters in filtering suspended particles and reducing pollutant loads can be explained by the role of each layer of filter material. Sand is effective in removing large particles and reducing turbidity, while gravel helps water flow and prevents clogging. Coconut shell charcoal and zeolite work by absorbing organic matter and other pollutants, which in turn reduces BOD and COD. This is in line with findings in previous studies showing that a combination of filtration materials can produce significant pollutant reductions. The decrease in TSS values indicates that this system can remove most of the suspended particles in water, which are often the main cause of water pollution.

The role of water hyacinth in the bioremediation process is also very important, because this plant has good phytoremediation capabilities. Water hyacinth is able to absorb excess nutrients such as nitrogen and phosphorus, which are often the main causes of eutrophication in water bodies. The measurement results show that this plant is effective in reducing nutrient levels in wastewater, which is also in line with research results showing that water hyacinth can reduce nitrogen and phosphorus content in wastewater. In addition, water hyacinth also helps improve water quality by absorbing organic compounds, which contributes to reducing BOD and COD.

Multi-stage filtration (MSF) combines coarse gravel filtration (CGF) with slow sand filtration (SSF), enabling the treatment of water with higher contamination levels than SSF can handle on its own. This system maintains the key benefits of SSF—being dependable and manageable by operators with minimal formal training. MSF is especially well-suited for rural areas, small to medium-sized towns in developing countries, and remote regions in industrialized nations, offering a more appropriate solution than chemical treatment methods. MSF systems can also be preceded by other processes such as sedimentation, sand traps, or screens. Whenever feasible, a final disinfection step should be included after MSF as an added safety measure [7].

The effectiveness of combining a multistage filtration system with phytoremediation using water hyacinth has been demonstrated in various studies. The significant reduction in BOD, COD, TSS, nitrogen, and phosphorus levels in domestic wastewater indicates that this technology can provide an efficient and sustainable solution for household-scale wastewater treatment [8]. This efficiency is also strongly influenced by the thickness and sequence of the filter media as well as the density of the aquatic plants used [9]. Numerous studies have shown that zeolite plays a critical role in reducing ammonia and heavy metals in wastewater due to its ion exchange and adsorption capabilities [10]. Meanwhile, activated carbon derived from coconut shells effectively absorbs organic compounds and enhances water quality [11], [12]. The combination of these materials provides a synergistic effect in reducing a wide range of pollutants.

Water hyacinth has been proven to absorb not only nitrogen and phosphorus but also heavy metals such as cadmium, copper, and lead with high efficiency [13]. Its extensive and dense root system makes it effective for filtering wastewater through rhizo-filtration and phytodegradation processes [14]. A study by Kalavathy et al. [14] revealed that *Eichhornia crassipes* could reduce BOD levels by up to 78% in less than 10 days [15]. Another study found that constructed wetlands using aquatic plants could reduce organic pollutants by more than 60% [16].

In densely populated areas, this system is also considered more economical compared to chemical-based or high-energy treatment technologies such as membrane filtration [17]. The use of locally available materials such as sand, coconut shell charcoal, and aquatic plants helps reduce operational costs while supporting the principles of appropriate and sustainable technology [15]. Furthermore, the implementation of this system does not require highly technical skills, making it operable by local communities ideal for rural and peri-urban areas [17]. MSF (Multistage Filtration) combined with wetlands or phytoremediation is highly flexible in design and can be adapted to suit local environmental conditions [17].

One of the main challenges in implementing this system is routine maintenance, particularly in preventing filter clogging and ensuring optimal growth of aquatic plants. Therefore, community education plays a vital role in ensuring the long-term effectiveness of this treatment system. A study [18], also noted that phytoremediation systems not only offer technical effectiveness but also provide ecological benefits such as increased microbial diversity and aquatic fauna [12]. Moreover, the combination of filtration and bioremediation is more stable in managing pollutant load fluctuations compared to single-treatment systems [15, 3].

In conclusion, the integration of multistage filtration and phytoremediation using water hyacinth is a promising alternative for sustainable domestic wastewater treatment in developing countries like Indonesia. This system supports the concept of a circular economy by utilizing organic waste and local plants as part of the water purification process [17].

Table 1. The treatment method of Media/organisms

No.	Treatment Method	Media/Organism	Parameters Studied	Average Efficiency	Additional Notes
1	Multistage Filter + Water Hyacinth	Sand, gravel, coconut shell charcoal, zeolite, water hyacinth	BOD, COD, TSS, N, P	BOD 65%, COD 60%, TSS 70%, N 50%, P 45%	Low cost, suitable for household scale
2	Three-Stage Filtration	Sand, activated charcoal, gravel	BOD, COD	BOD 55%, COD 58%	Efficient for households, but phytoremediation not tested
3	Plant-Based Biofilter	Water hyacinth	BOD, Nitrate	BOD 70%, Nitrate 60%	Uses only plants, no filter system
4	Multistage Sand Filter	Coarse-fine sand	TSS, Turbidity	TSS 68%	Does not target nutrient parameters
5	Constructed Wetland	Typha sp., Zea mays	BOD, COD, NH_3	BOD 60%, COD 55%, NH_3 40%	Requires large area
6	Sand + Charcoal Filter	Fine sand, coconut shell charcoal	COD, Color	COD 50%	Limited effectiveness with only sand and charcoal media
7	Aquatic Plants + Biofilter	Pistia stratiotes + stone filter	BOD, COD, P	BOD 58%, P 42%	Combination of passive and active systems

8	Anaerobic Baffled Reactor + Biofilter	Concrete reactor + zeolite media	COD, TSS	COD 75%, TSS 65%	Requires intensive maintenance
9	Slow Sand Filter	Sand, zeolite stone	TSS, pH	TSS 62%, stable pH	High efficiency, but slow process
10	Vertical Biofilter	Activated charcoal, sand	COD, BOD, Nitrate	COD 65%, BOD 60%, Nitrate 45%	Requires optimization of media thickness

3. Conclusion

The integration of multistage filtration and water hyacinth *(Eichhornia crassipes)* bioremediation presents an effective, low-cost, and environmentally friendly method for treating household wastewater. The multistage filter system, utilizing sand, gravel, coconut shell charcoal, and zeolite, significantly reduces levels of BOD, COD, and TSS, while the phytoremediation capability of water hyacinth effectively decreases nitrogen and phosphorus concentrations. This combined method achieved pollutant removal efficiencies of up to 65% for BOD, 60% for COD, 70% for TSS, 50% for nitrogen, and 45% for phosphorus. These results demonstrate that this method is suitable for household and small-scale community applications, particularly in areas lacking centralized wastewater treatment infrastructure. Moreover, it aligns with sustainable development goals by offering an accessible and replicable solution for improving water quality. However, to maximize its long-term effectiveness, further research is recommended to optimize system design, plant management, and pollutant load variability under different environmental conditions. Future studies should also explore the integration of disinfection steps and investigate potential applications for treating other types of wastewater.

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