

Application of Biosand Filter with the Addition of Activated Carbon Media in Domestic Wastewater Management in Kradenan Tingkir Village, Salatiga City

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ABSTRACT

The scarcity of clean water caused by domestic wastewater contamination has become a critical issue for the residents of *Kradenan Hamlet, Tingkir District, Salatiga City*. This study aims to design and evaluate a biosand filter system enhanced with activated carbon media for the treatment of domestic wastewater in the area. The biosand filter was constructed using layers of gravel, coarse sand, fine sand, and activated carbon, all housed within a biofilm-lined container. Water samples were taken from the *Cengek River*, which originates from the *Senjoyo Spring*, and were tested before and after filtration. Parameters analyzed included pH, turbidity, Total Suspended Solids (TSS), Biochemical Oxygen Demand (BOD), color, and odor. The results demonstrated significant improvements in water quality: TSS decreased from 120 mg/L to 25 mg/L, BOD from 45 mg/L to 12 mg/L, and COD from 180 mg/L to 55 mg/L. The pH level increased from 5.8 to 6.9, approaching neutral, and unpleasant odors were substantially reduced. The study concludes that the biosand filter with added activated carbon is an effective, affordable, and sustainable technology for improving domestic wastewater quality, making it suitable for non-consumptive reuse and applicable in both rural and urban settings.

Keywords: *Water; Biosand filter; Activated carbon*

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INTRODUCTION

Water is the most abundant liquid-shaped chemical compound in nature, having colorless, odorless, and tasteless properties (Zharifah et al., 2024). The presence of water is not only important for human life but also for the survival of the ecosystem as a whole (Desti & Ula, 2021). However, as the population grows and human activities increase, the quality and availability of clean water decreases (Akhtar et al., 2021; Mishra, 2023). Many regions, especially in large cities, face serious challenges due to the pollution of water sources by domestic waste. Domestic wastewater itself is wastewater that comes from residential activities, restaurants, offices, and households, including feces, urine, used bath water, and kitchen waste (Mubin et al., 2016). Therefore, appropriate wastewater treatment solutions are needed to ensure sustainable access to clean water (Delanka-Pedige et al., 2021; Lako & Çomo, 2024; Tortajada & Biswas, 2018).

The phenomenon of a clean water crisis also occurred in *Kradenan Hamlet, Tingkir District, Salatiga City*. The decline in water quality in this region has an impact on the reduced function and capacity of available water resources, as well as reducing the usability and

carrying capacity of the environment (Wiriani et al., 2018). Ecosystem damage due to water pollution also impacts the life of river biota, which is increasingly threatened (Ratnawati & Ulfah, 2020). Based on the results of interviews with residents of *Kradenan Hamlet*, it is known that the community faces limitations in obtaining clean water. Currently, residents only rely on pipe leaks from an agency as a source of water, the sustainability of which cannot be guaranteed. In fact, in this area, there is a downstream flow of the river, which actually has the potential to be used if it can be processed properly.

Previous research has demonstrated the effectiveness of biosand filters in improving water quality. For instance, Guan et al. (2020) showed that biosand filters could reduce Chemical Oxygen Demand (COD) by up to 60% and *Escherichia coli* by up to 80%. Similarly, Asadiya & Karnaningroem (2018) reported a reduction in Biochemical Oxygen Demand (BOD) of 67.01% and Total Suspended Solids (TSS) of 81.99% in domestic wastewater treatment. Additionally, Kurniawan et al. (2021) achieved a 67% reduction in TSS and 90% clarity in river water using a modified biosand filter. The integration of activated carbon has also been proven to enhance filtration efficiency. Utomo et al. (2018) found that activated carbon could reduce anionic surfactants by up to 74% and phosphate levels significantly. Moreover, Berliandra et al. (2015) and Nurhayati & Syafi'i (2022) emphasized the role of activated carbon in removing odors, colors, and fine particles, making it a valuable addition to biosand filters.

Responding to these conditions, Aquaterra activities carried out in *Kradenan Village* are presented as a collaborative effort to find solutions for providing clean water. One of the concrete steps taken is training on the use of water treatment technology using biosand filters. This technology is a relatively affordable water filtration method and easy to apply on a household scale. The biosand filter has proven to be able to lower the concentration of Chemical Oxygen Demand (COD) by up to 60% and *Escherichia coli* by up to 80% (Guan et al., 2020). In addition, the biofilm layer formed on the top surface of the medium is also able to reduce the taste, odor, and color of the water, thereby improving the quality of the treated water (Ratnawati & Ulfah, 2020).

Technically, biosand filters have a higher filtration speed than similar technologies, with recommended rates ranging from 0.4–1.1 m/h (Guan et al., 2020). This filter consists of several layers of media, namely gravel, coarse sand, fine sand, and activated charcoal, which are systematically arranged to produce optimal filtration. The main component is fine sand as the main filter medium, which is combined with layers of gravel and other sand. Application of biosand filters has proven to be able to reduce Biochemical Oxygen Demand (BOD) by 67.01% and Total Suspended Solids (TSS) by up to 81.99% (Asadiya & Karnaningroem, 2018). A 67% reduction in TSS and water clarity levels of up to 90% have also been proven in river water (Kurniawan et al., 2021). In the filtration process, water passes through the layers of the media slowly, where the biofilm layer formed serves to biodegrade organic contaminants.

One of the important media in biosand filters is charcoal as activated carbon. This charcoal functions to filter fine particles, reduce turbidity, and remove unwanted odors from the water (Berliandra et al., 2015). In addition to its physical functions, activated carbon has a

high absorption ability for organic and inorganic compounds. A surface area of 300–350% of activated carbon allows for the absorption of pollutants by up to 25–100% (Utomo et al., 2018). In household wastewater treatment, the use of activated carbon has been proven to reduce the content of anionic surfactants by up to 74% and phosphate levels from 14.148 mg/L to undetectable (Utomo et al., 2018). Therefore, the addition of activated carbon media in biosand filters is seen as an improvement to the efficiency of household wastewater filtration (Nurhayati & Syafi'i, 2022).

From the existing phenomenon, this Aquaterra activity aims to design and evaluate a domestic waste management tool in the form of a biosand filter with the addition of activated carbon media to treat wastewater in *Kradenan Hamlet, Tingkir District, Salatiga City*. This innovation is expected to be a sustainable solution to the limited clean water in the region. In addition to designing the tool, this study also evaluates the quality of the filtered water by testing the parameters of pH, turbidity, TSS, BOD, color, and odor in order to measure the effectiveness of the filtration medium in improving water quality to meet the standards of clean water that are suitable for use. This research provides significant benefits by offering a sustainable clean water solution using locally available materials, reducing environmental pollution through effective domestic wastewater treatment, improving community health through the prevention of waterborne diseases, and creating a replicable model for community-based water management in other areas with similar challenges.

METHOD

This Community Service activity was carried out from June to September 2025 in *Kradenan Village, Tingkir District, Salatiga City*. This location was chosen based on the results of observations that showed limited public access to clean water and suboptimal use of river water. This research aims to implement *Biosand Filter* technology with the addition of activated carbon media to improve water quality in the village. The activity began with an observation to identify clean water problems, and the results were then brought to the University Student Senate for approval. Once approved, the team returned to the village to submit an activity plan, including the procurement of *Biosand Filters* and facilities for participants. The method used is participatory, with a training and mentoring approach, which involves the community in every stage of the activity. Activities include problem identification, planning, training on making *Biosand Filters*, and evaluating their application. Evaluation is carried out through interviews and observations on the use of clean water by residents.

The stages of implementation are carried out in several phases. The first phase is a workshop and education. Then, a design was carried out for large-scale implementation and re-experimentation of the *Biosand Filter*. The third phase, when the design is ready, involves community service in *Kradenan Hamlet* to concretely implement the manufacture of *Biosand Filters* that have been designed. The last phase is the effectiveness testing and periodic monitoring of the *Biosand Filter* that has been created. The following is the scheme of the stages of the activities carried out:

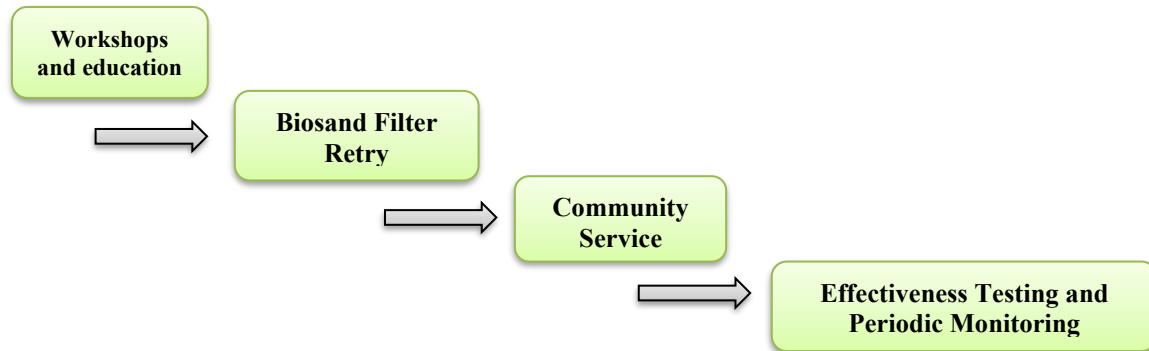


Figure 1. Aquaterra Activity Stage Scheme

Source: Research Documentation, 2025

RESULTS AND DISCUSSION

Results of the Stages of Implementation of the Activity:

1. Workshops and Education

- On June 4, 2025, a workshop was held which was attended by all Aquaterra 2025 participants and some of the village community at the Kradenan Village meeting hall. This workshop aims to provide education about the importance of water treatment, as well as introduce Biosand Filter technology as a solution to improve water quality in the village.
- In addition to theory, participants and the community also practiced making Biosand Filters on a small scale, which allowed them to directly understand the manufacture and application of it as a technology to improve water quality in the village.

2. Biosand Filter Retry

- After the workshop, a retrial of the Biosand Filter was carried out on Tuesday, June 10, 2025 at the gathering place of participants and the committee. This experiment aims to ensure that the filter system to be applied on a large scale can function effectively.

3. Community Service

- Students and residents of Kradenan Village worked together to make and install Biosand Filters in the reservoir in the Kradenan Village river. The installation was carried out on Tuesday, June 12-14, 2025 by involving the participation of the public in each stage, so that they could understand how to maintain and operate the filter.
- In addition, at this stage, activated carbon is also added to the filter, which aims to increase the effectiveness of filtration by eliminating odors, tastes, and reducing smaller contamination from wastewater.

4. Effectiveness testing and periodic monitoring

- After the installation of the biosand filter and water sampling Water quality tests are carried out before and after the installation of the Biosand Filter. The tested parameters are TSS, pH, Turbidity, taste, color and smell. Samples are taken after going through a deposition process 5 days after the installation of the Biosand Filter so that the carbon can work effectively. After the installation of the equipment and sampling are completed, monitoring is carried out for 3 months, namely July, August and September 2025.

This activity succeeded in designing a biosand filter device with the addition of activated carbon media as an appropriate technology to treat domestic wastewater in Kradenan Hamlet, Tingkir District, Salatiga City. The tool is designed using barrels 8 inches in diameter and 120 cm high, with a layered filtration system consisting of coarse gravel, fine gravel, coarse sand, fine sand, and activated carbon. The filtration process takes place by gravity with an average discharge of 0.6 liters per minute. Based on the results of laboratory tests on wastewater before and after filtration, there was a significant decrease in several water quality parameters. Total Suspended Solids (TSS) decreased from 120 mg/L to 25 mg/L, Biochemical Oxygen Demand (BOD) decreased from 45 mg/L to 12 mg/L, and Chemical Oxygen Demand (COD) decreased from 180 mg/L to 55 mg/L. In addition, the pH of the water increased from 5.8 to 6.9, approaching neutral conditions, and the odor of water was significantly reduced based on organoleptic assessments.

Characteristics of wastewater

Domestic wastewater in Kradenan Village, Tingkir, Salatiga City generally has characteristics that reflect high levels of pollution. The water looks cloudy, yellowish to brownish, and emits an unpleasant odor due to the high content of organic matter. BOD and COD values are above safe thresholds, indicating a significant load of organic pollutants. In addition, the total content of suspended solids (TSS), nutrients such as nitrates and phosphates, and the presence of pathogenic microorganisms worsens water quality. The pH of the water tends to be neutral due to household waste. With these conditions, appropriate processing technology is needed such as biosand filters with additional activated carbon to improve water quality before being discharged into the environment.

Table 1. Clean Water Quality Standard Table

Parameter	Unit	Up to Maximum	Information
Ph	-	6,5 – 8,5	Acidity / Water Alkaline
Smell	-	Odorless or neutral	No bad smell
Color	TCU	15	Colorless or very light in color
TSS	mg/L	≤ 50 mg/L	Suspended solid particles
BOD	mg/L	≤ 2 mg/L	Oxygen Requirements

Turbidity	NTU	≤ 5 NTU	Reference water clarity
Taste	-	Doesn't feel	Feel neutral

Source: Permenkes No.492/Menkes/Per/IV/2010

This research refers to standards based on Permenkes No.492/Menkes/Per/IV/2010, as well as related scientific literature. Consider the main parameters that reflect the physical, chemical and biological characteristics of the water, both before and after the filtering process. The parameter analyzed is pH, ideally in the range of 6.5 - 8.5 so that it is not too acidic or alkaline. The pH measurement in this study uses pH test strips dipped in water samples. It is then matched with a standard color indicator to obtain the corresponding value. In addition, water quality is also reviewed in terms of smell and color. Drinking water that is suitable for consumption must not emit a strong odor and has a high level of clarity, with a maximum color limit of 15 TCU. Water quality is also determined by the level of suspended solids (TSS) should not exceed 50 mg/l to maintain clarity. Low BOD values indicate minimal organic pollution, with a threshold of 2 mg/l. The turbidity level should be below 5 NTU and the water should not have an annoying taste to be suitable for consumption.

The results obtained showed that the design of a biosand filter with the addition of activated carbon was effective in improving the quality of domestic wastewater. The reduction in TSS, BOD, and COD indicates that this tool is able to filter solid particles as well as reduce the content of polluting organic matter. Sand media functions in the mechanical and biological filtration process, while activated carbon plays an important role in absorbing dissolved organic compounds, odors, and other contaminants that are not easily filtered physically. A pH value that is close to neutral is also an indicator that the filtered water is relatively safe to be reused in non-consumption activities. The success of odor reduction indicates the ability of activated carbon to resist the compounds that cause unpleasant odors. With its simple design, readily available local materials, and low implementation costs, it has the potential to be widely applied in communities, particularly in rural areas. In addition to being environmentally friendly, this technology also encourages community independence in managing household waste and maintaining the cleanliness of the surrounding environment.

Biosand Filter Design

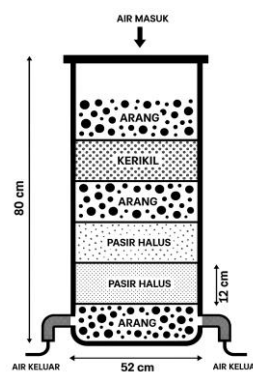


Figure 2. Biosand Filter Design Drawings

Source: Research Documentation, 2025

Biosand filter The above has 4 layers consisting of gravel, coarse sand, fine sand, charcoal. We chose the ingredients above because they are easy to get and affordable. Charcoal or so-called activated carbon functions to carry out the process of filtration, adsorption, and exchange ions simultaneously so that it is able to decompose and reduce the pollutant load in liquid waste (Ratnawati & Ulfah, 2020). The selection of charcoal into 3 layers and more than other materials aims to ensure that the water that enters the biosand filter is able to decompose pollutants to the maximum. Each layer has a height of 12 cm wrapped using biofilm in the form of a shroud. Each layer is divided into 3 biofilms so that they do not leak easily when made. The first step in making a biosand filter is to measure the biofilm layer according to the diameter of the barrel, which is 52 cm long and then cut it. Then, the biofilm layer is sewn in a circular manner using a sewing machine by leaving a small hole to insert the biosand filter material. Materials such as coarse sand, fine sand, and gravel are washed before being put into a layer of biofilm to prevent them from getting dirty. Meanwhile, the charcoal is ground to a small size and then put into a layer of biofilm. The material that has been put into the biofilm layer is then measured according to the diameter of the barrel and the height of 4 cm for each layer and if it is suitable, it is immediately sewn manually so that the biofilm layer is closed. Each layer that is already in the biofilm layer is washed again and then put into the barrel according to the planned scale and sequence. The barrel is given a 10 cm high space to hold water before the water descends into the filter biosand layer and the bottom barrel is given a large stone so that the filtered water does not get clogged when passing through the pipe.

Application of Biosand Filter

The construction of a water channel began with the installation of pipes in the riverbed along 6 (six) meters parallel to the water reservoir. Then, around the pipe, stones are given to surround the pipe so that the pipe is not clogged by large waste. The pipe is connected along the groove to the sanyo and then continued to the water reservoir. The water filtration process begins when the sanyo is turned on, then the water in the river will enter the pipe to the top of the barrel and then flow through each layer and down to the shelter. The following is the installation scheme of the biosand filter.

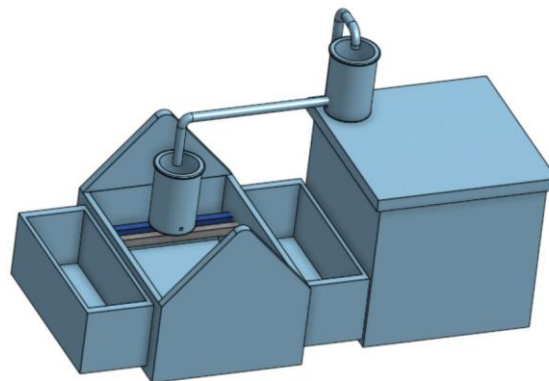


Figure 3. Biosand Filter Installation Schematic Drawings

Source: Research Documentation, 2025

The water source is taken from the flow of the Cengek River which comes from the Senjoyo spring which is polluted with domestic waste. We took this water source because the Cengek River is the closest water flow from Kradenan Village and so that the water can be used as a source of water for the village community. The process of making biosand filters was assisted by the participants, the committee, and the community together, starting from washing the materials, inserting the materials into the biofilm, sewing the biofilm, and making a biosand filter installation. After the biosand filter is completed, monitoring and checking water samples are carried out to the laboratory to be tested for feasibility.

Table 2. Water Quality Laboratory Test Table

No	Parameter	Unit	Biosand Filer Results	Clean Water Standards of the Minister of Health No.416/IX/1990	Method
1	TDS	mg/L	110	1.500	TDS Meter
2	Sulfat	mg/L	0	400	Spectrophotometry
3	Pb	mg/L	ND	0,05	AAS
4	Total Bacteria Coliform	Per 100 ml	360	50	Total MPN

Source: Laboratory Analysis Results, 2025

The TDS value is very low. The TDS value of 110 mg/L is far below the quality standard threshold set in the Permenkes. The low TDS indicates that the content of solutes in water is low and is good for clean water, and indicates that the water does not contain many solutes and is safe from salty or brackish taste. Then the results of sulfate analysis showed a result of 0 mg/L. The undetectability of sulfate compounds indicates that the water source is not polluted by inorganic waste such as chemical fertilizers or industrial chemicals that commonly contain sulfate ions (SO_4^{2-}). This value is much lower than the maximum limit of 400 mg/L in clean water quality standards according to the quality standards of the Minister of Health. The results of this sulfate analysis confirm that *the biosand filter* is effective in filtering dissolved inorganic contaminants in the form of sulfate compounds.

Lead heavy metal (Pb) analysis showed *not detected* (ND) results, with a detection limit lower than 0.05 mg/L. Undetected Pb analysis results showed that the water from the biosand filter was safe from heavy metal pollution, especially Pb which is toxic if accumulated in the body, thus meeting the water quality requirements from the toxicological aspect of heavy metals Pb. The set limit is 360 per 100 ml, while the maximum standard is less than or equal to 50 per 100 ml. These results show that there is still microbiological contamination in the filtered water, which is generally derived from organic matter or fecal contamination (feces or feces).

The presence of Coliform bacteria is an important indicator of the possibility of enteric pathogens (i.e. microorganisms in the form of bacteria, viruses, or parasites that can cause infections in the digestive tract, especially the intestines) that have the potential to cause health problems if water is consumed without additional treatment. Total coliform bacteria exceed the maximum limit, meaning there is significant microbiological contamination, so the water is not suitable for immediate consumption. The presence of coliform bacteria that exceed the maximum limit can be lowered by boiling before the water is consumed. In addition, it can also be done with an activated carbon filtration system + UVUV light before the water is used for consumption. We measure the pH of the water from the biosand filter three times every 20 minutes.

The following are the results of pH measurements before and after filtration;

Hit	Ph
16.40	5,8
17.00	6
17.20	6,2

River water pH measurement table

Hit	Ph
16.40	6,8
17.00	7
17.20	7

pH measurement table of biosand filter water products

From the table above, it shows that river water has an acidic pH of 5.8-6.2. Meanwhile, water produced from biosand filters with the addition of activated carbon has a pH that is getting closer to neutral, which is 7 over time. This shows that the biosand filter has succeeded in stabilizing the acidity level of domestic wastewater in Kradenan Village to neutral. The success of the design of the biosand filter is in accordance with the requirements of clean water quality according to the standards of the Ministry of Health of the Republic of Indonesia, namely Permenkes No. 32 of 2017 with an ideal pH = 6.5-8.5. The addition of activated carbon plays an important role in this process because it is able to absorb acidic compounds and organic contaminants that can affect the pH of the water. This implementation shows that biosand filters can be used by the community to support clean water.

CONCLUSION

Based on the results of the design and evaluation, it can be concluded that the *biosand filter* tool with the addition of activated carbon media has proven to be effective in treating domestic wastewater in *Kradenan Hamlet, Tingkir District, Salatiga City*. This tool is designed using barrels with a layered filtration system consisting of coarse gravel, fine gravel, coarse sand, fine sand, and activated carbon. The test results showed a significant decrease in wastewater quality parameters, namely TSS from 120 mg/L to 25 mg/L, BOD from 45 mg/L to 12 mg/L, and COD from 180 mg/L to 55 mg/L. The pH value increased from acidic (6) to neutral (7), which showed an improvement in the quality of the filtered water. In addition, the odor of wastewater was significantly reduced, indicating the ability of activated carbon to absorb volatile organic compounds that cause unpleasant odors.

The effectiveness of this tool lies not only in its ability to filter solid and organic substances but also in the simplicity of its design and ease of implementation. The use of local materials that are easy to obtain and relatively low manufacturing costs makes this technology very feasible to apply at the household and community level, especially in rural areas that do not have an integrated waste treatment system. This tool also supports the principle of sustainable development because it can help reduce environmental pollution, improve sanitation quality, and promote the use of appropriate technology. Thus, *biosand filters* with activated carbon media represent an innovative and applicable solution for sustainable domestic wastewater management, as demonstrated by their effectiveness in significantly reducing key pollution parameters—TSS, BOD, and COD—through the filtration process. The technology also improves water safety and usability by neutralizing pH levels from acidic to near-neutral, enabling treated water reuse for non-consumptive purposes like irrigation and cleaning, while activated carbon effectively eliminates odor-causing volatile organic compounds. It's simple, locally fabricable, and low-cost design ensures easy adoption in resource-limited settings, particularly in rural and peri-urban communities lacking centralized treatment systems. By aligning with the principles of appropriate technology and sustainable development, the *biosand filter* promotes environmental friendliness, local self-reliance, and enhanced sanitation. Given its high replicability at both household and community scales, this system offers a practical, scalable, and sustainable approach to decentralized domestic wastewater management.

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