



Natural Material-Based Water Filtration to Provide Clean Water for Semaja Village, Bali

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Abstract. This study addresses the water quality issues in Semaja Village, where surface river water, the main source, becomes highly turbid during the rainy season. Managed by the “Pancoran Sari” group, the existing water supply system lacks thorough water quality testing, raising health concerns. To improve water safety, a natural filtration system using locally available pumice stone and activated carbon was developed. Pumice acts as a physical filter, removing sediments, while activated carbon adsorbs organic contaminants. Laboratory tests showed significant improvements: Chemical Oxygen Demand (COD) dropped to 11.973 mg/L, iron levels reduced to 0.641 mg/L, Total Dissolved Solids (TDS) decreased to 168 mg/L, and Biological Oxygen Demand (BOD) improved to 1.512 mg/L. The natural filtration system effectively enhances water quality and provides sustainable access to clean water for the community.

Keywords: Clean Water Sources, Natural Filtration, Semaja Village Community

1 Introduction

Water is an essential material element for the life of living beings, especially humans. The sustainability of life on Earth depends on the availability of water from various sources (Julaikah & Astuti, 2023). The supply of clean water is extremely important and constitutes a basic need. Water is a crucial necessity for human life, and the scarcity of clean water, particularly in remote areas of Indonesia, forces communities to use water that does not meet health standards (Armansyah et al., 2022). All living beings require clean water, especially humans, to fulfill various needs in their daily lives. For water to be used for human purposes, its quality must meet the specified quality standards. In addition to meeting the quantity and quality requirements of water sources, the use of these sources must also comply with water quality criteria according to their intended use. Clean water that is biologically or chemically contaminated or does not meet established standards can endanger public health or the population in a short period of time. One widely used water purification method is filtration. Water purification through filtration has been proven to improve the quality of well water, bringing it within acceptable limits for daily use, including for consumption and cooking (Syafitri et al., 2023; Widodo et al., 2023).

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Semaja Village, located in Selemadeg Barat District, Tabanan Regency, Bali Province, covers an area of approximately 2.44 km² or 2,440,000 m², with a population of 108 households. The residents of Semaja Village have the following occupations: 35% work in the formal sector, while the remaining 65% are farmers. The geographical condition of Semaja Village is hilly and surrounded by a river situated in a valley approximately 100 meters below the residential and agricultural areas. The irrigation system for the rice fields, known as *subak*, is sourced from the Pancoran River, which flows through Bengkel village. This river, which serves as the water source for irrigation, is rain-fed, meaning that during the dry season, the river's water discharge decreases drastically, making it unable to irrigate the rice fields in Semaja Village adequately.

The condition of the community during the dry season is very concerning, as income from rice farming decreases, and in some cases, their rice crops fail due to water shortages. Meanwhile, they need additional money to purchase clean water for their family's consumption needs. In response to this situation, the people of Semaja Village conceived the idea of constructing a clean water installation that would channel water directly from the source to each household.

In August 2024, the Pancoran Sari clean water group built a main reservoir to collect water flow from the Pancoran River and installed a water pipe system through self-help and self-funding efforts. The clean water facilities established by this community group have been able to supply water to each household. Currently, the installation providing the clean water source is operational and can be utilized; however, during the rainy season, the water becomes turbid, as seen in Figure 1.



Figure 1. Condition of the River as a Water Source for the Semaja Village Community

This clean water source is taken from the river, which is surface water, and the raw water has not yet undergone laboratory testing to determine its suitability. The Pancoran Sari clean water group manages the available clean water facilities in Semaja Village. The existence of this clean water group greatly assists the community in providing clean water for households. Technically and institutionally, this group still lacks adequate supporting facilities, both in terms of human resources and technical completeness in managing the clean water system. Based on the current conditions, several problems can be identified. The water source used is river water located upstream in the village, but until now, no laboratory testing has been carried out to determine the suitability of its elemental content. In addition, the water installation lacks filtration facilities, despite the river water source being turbid. The main pipeline installation from the water source to the first reservoir upstream is also not equipped with a strainer. This device captures solid particles carried by the water flow, which causes blockages at several points due to mud and sand. Furthermore, the human resources managing the system still require

training on installation, maintenance, and the proper care of the water filtration facilities in use.

2 Methodology

The small group discussion method serves as a foundational approach in implementing community service programs (Clobridge, 2010). The process begins with collaborative discussions between the implementation team and the clean water group partners in Semaja Village. This initial phase involves gathering detailed information about the partners' challenges and clearly communicating the program's purpose and objectives, which include the implementation schedule, team capacity, funding models, and operational procedures. The discussions focus on categorizing the partners' issues, such as constructing buffers or partitions for natural filter media in upstream reservoir tanks, fabricating and installing natural filter media, developing management skills for maintenance and repair of installations, and organizing business administration.

Through this participatory discussion process, alternative solutions are proposed that encourage active involvement from both the group members and managers to enhance service quality. Subsequently, a mutually agreed-upon activity schedule is developed between the implementation team and the partners to guide the program's execution. The program proceeds on a scheduled basis, with training sessions led by instructors from the implementation team, tailored to address the specific problems faced by the partners and aligned with the proposed solutions. Following training, ongoing mentoring and assistance are provided according to the agreed timeline.

The program emphasizes training and mentoring in both business management and practical skills required for the maintenance and repair of filter installations and clean water pipeline networks. By applying natural filter installations and maintaining well-functioning pipeline systems, the clean water group's enterprise is expected to sustain and grow, ultimately delivering economic benefits to the community.

In parallel, the overarching goal of water treatment within this context is to reduce pollutant concentrations to ensure water safety. Adapting treatment methods to the unique characteristics of water sources is critical to meeting demand and overcoming water availability challenges. This necessitates technology adapted to the raw water properties, environmental conditions, socio-cultural factors, and local human resource capabilities.

The initial study phase focused on evaluating two filtration systems: a slow filter composed of silica sand, gravel, and activated carbon functioning as a single filtration unit, as seen on Figure 2, and a layered natural media filter system with activated carbon on top, gravel in the middle, and silica sand at the bottom, each housed separately, as seen on Figure 3. The research assessed the impact of raw water turbidity and filtration rates on treated water quality, particularly turbidity reduction and coliform removal, while also monitoring filter performance through head loss observations. These investigations provide critical insights to optimize filtration technology suited for the community's needs.

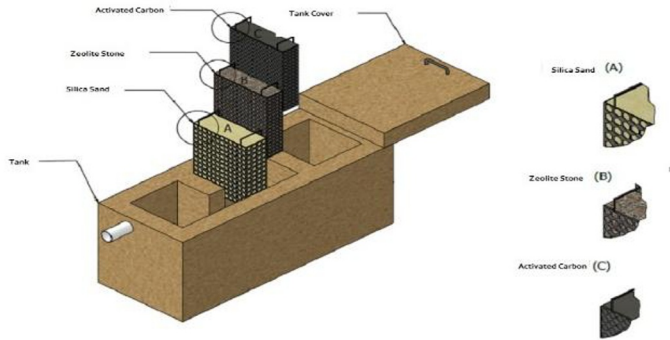


Figure 2. Filter Construction Design with Natural Media (Waisnawa et al., 2024)

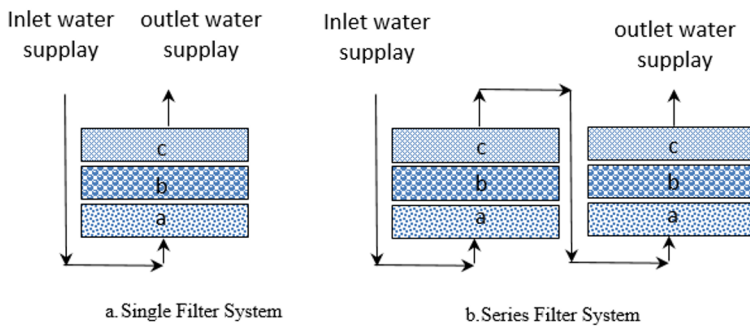


Figure 3. Filter System (Waisnawa et al., 2024)

3 Result and Discussion

3.1 Result

Socialization and direct site visits to the partner location are conducted to convey the activity plan and adjust it according to the priority scale of problems, based on the approved time and budget allocation. Agreement on the activity schedule will facilitate the smooth implementation and realization of the planned activities. The results of the small group discussions produced several agreements regarding problems, solutions, and their realization, as shown in Table 1.

Provision of filter materials such as pumice, activated carbon, and equipment for improving the water pipe installation by adding drainage channels to reduce sedimentation of mud or fine sand entering the pipeline. The construction of filtering/filtering equipment, as seen on Figure 4, includes: a) a debris filter for the water inlet channel from the river to the reservoir and sedimentation tank; this filter functions to screen materials such as dry leaves, dry twigs, sand, and gravel, as well as to prevent fish and crabs from entering the reservoir; b) construction of concrete partitions in the sedimentation tank to create three chambers for mud and sand settling; c) construction of filter media holders for arranging media layers consisting of silica

sand, pumice stone, and activated carbon (coffee charcoal); d) packaging of filter media: pumice stone and activated carbon (charcoal) using fine mesh bags.

Table 1. Realization of Problem Solving

No.	Problem	Solution	realization
1	The water source is a river or surface water that is murky in the rainy season	Add natural filter media, which is placed in the settling tank	Making a buffer/screen for natural filter media: Silica sand, zeolite stone, and activated carbon
2	The water source has never been laboratory tested to determine its chemical element content	Carrying out laboratory tests on raw water	Taking test samples before installing the filter and after installing the filter
3	The main water distribution pipe network installation is often clogged with silt and sand deposits.	Installation of filters or solid particle catchers carried by the water flow in the installation pipe.	Provision and installation of strainers at 4 points with proportional distances
4	Increasing the skills of clean water managers in the field of maintaining clean water pipe installation networks, natural filter media, and other business management.	Increasing the skills of clean water managers in the field of maintaining clean water pipe installation networks, natural filter media, and business management	Training and Assistance in the maintenance of water filters and raw water pipe installation networks



Figure 4. Construction of Filtering Equipment

Draining sediment and fine sand from the bottom of the first water reservoir tank located at the river, which serves as the raw water source. The draining and cleaning are carried out to reduce the sediment content in the raw water stored and flowing into the filter media. The installation of filters and filter media begins with transporting the equipment from the clean water group’s secretariat to the upstream water source, which is approximately 2 kilometers away. The installation activities, as seen in Figure 5, are carried out collaboratively by group members, the implementation team of lecturers, and students. After installation, a trial run is conducted by flowing water through the filter media.



Figure 5. Installation of Filters

Laboratory testing was conducted after the application of natural material filtration, using water samples taken both before and after the filtration process. The samples were analyzed at the Analytical Laboratory of Udayana University. The parameters tested included Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Dissolved Solids (TDS), turbidity, and metal content such as lead (Pb) and iron (Fe). Laboratory test results are shown in Table 2.

Table 2. Laboratory Test Results of COD, BOD, TDS, and Turbidity

No.	Parameter	Method	Unit	Filtration Result			Allowed maximum Limit*
				Before	1 Layer	2 layer	
1	COD	Titrimetry	mg/L	15,360	9,600	3,840	10
2	BOD	Titrimetry	mg/L	8,064	5,040	1,008	2
3	TDS	Titrimetry	mg/L	810,00	790,000	670,000	1.000
4	Turbidity	Spectro-photometry	mg/L	1.016,161	910,411	126,365	1.000

* Republic of Indonesia Government Regulation Number 22 of 2021 Concerning Implementation of Environmental Protection and Management

Based on the results of laboratory tests on the content of metal elements and bacteria, the following test results were shown in Table 3.

3.2 Discussion

The construction of water filters and filtration systems using natural materials has been completed. The filtration operates by gravity with a height difference of just 0.6 meters, necessitating frequent cleaning of sediment buildup in the settling tank, especially during the rainy season when river water turbidity increases. At present, the drain channels of both the settling and filter tanks require replacement with threaded clean-out plugs to facilitate easier removal of sediment from the bottom of the storage tanks. The filtered water produced is noticeably clearer than the untreated river water.

Table 3. Laboratory Test Results of Metal Elements and Bacteria

No	Parameter	Unit	Result	Allowed maximum limit*
Physics				
1	Temperature	°C	27.2	Air temperature ±3
2	Turbidity	mg/L	3.15	5
3	Dissolved Substance	mg/L		1500
Chemistry				
4	pH	mg/L	8.2	6.5-9.0
5	Nitrate	mg/L	4.7	10
6	Nitrite	mg/L	3.2	1.0
7	Cadmium	mg/L	0.07	0.005
8	Zinc	mg/L	0.01	15
9	Ferro (Fe)	mg/L	0.06	1.0
10	Cromium (Cr)	mg/L	0.03	0.05
Bacteriology				
1	E.Coli	MPN/100mL	8	50
2	Total Coliform	MPN/100mL	1910	10

Based on the test results of water samples taken before and after the filtration process, there was a decrease in the parameter values (COD, BOD, TDS, and turbidity) as shown in Table 2. The tested parameter values have met the quality standard thresholds for raw water sourced from the river water (Wulandari, 2019; Atima, 2015). The clean water source used meets the requirements as a raw water source for sanitation needs (bathing, washing, and toilet use). The use of natural filtration materials in treating water has led to notable enhancements in water quality (Dewi, 2015; Rizki, 2021). Chemical Oxygen Demand (COD) levels dropped from 15,360 mg/L to 3,840 mg/L after passing through two filtration layers, although this value remains above the acceptable limit of 10 mg/L. Similarly, Biological Oxygen Demand (BOD) decreased from 8,064 mg/L to 1,008 mg/L with the two-layer filtration, yet it still exceeds the permissible threshold of 2 mg/L. Total Dissolved Solids (TDS) showed a slight reduction from 810,000 mg/L to 670,000 mg/L, which is still within the maximum allowed limit of 1,000 mg/L. Turbidity, assessed via spectrophotometry, significantly declined from 1,016.161 mg/L to 126.365 mg/L but remains above the maximum limit of 1 mg/L. In summary, although the filtration system greatly improves water quality, additional improvements are necessary to meet all health standards requirements.

Based on laboratory test results of the clean water source that has undergone natural filtration, the physical parameters generally meet the requirements. However, some chemical parameters exceed the maximum allowable limits, such as Nitrite as N. In terms of bacteriological parameters, the E. coli levels are below the permitted standard, but the total Coliform count exceeds the maximum allowable limit, as seen in Table 3. The clean water source is river water, which is surface water and therefore highly vulnerable to contamination from waste in the river's watershed area (Anh et al., 2023). For households using this water as clean water, if it is to be used for drinking, it must be boiled at 100°C for 5 to 20 minutes.

In addition to demonstrating the reduction in COD, BOD, TDS, and turbidity parameters, the results of this study also indicate certain limitations of the natural filtration system, particularly for parameters that still exceed the quality standards, such as COD, BOD, nitrite, and total coliform. This is most likely due to the limited capacity of the filtration media (pumice and activated carbon) to remove dissolved organic compounds and pathogenic microorganisms, especially considering that the water source comes from surface runoff affected by upstream activities. Another contributing factor may be the relatively high flow rate through the filter during periods of large water discharge, which reduces the contact time between the water and the filtration media, thereby limiting the adsorption and biological filtration processes.

Compared to the findings of Dewi (2015) and Rizki (2021), natural filtration is indeed more effective in reducing turbidity and suspended solids than in eliminating dissolved organic matter. Therefore, in the case of Semaja Village, this system is sufficient for sanitation purposes (bathing, washing, and toilet use) but is not yet completely safe for direct drinking without further treatment. To achieve potable water standards, an additional treatment step, such as disinfection (chlorination or UV irradiation) or a reduction in filtration flow rate to increase contact time, is recommended.

From a sustainability perspective, the significant reduction in turbidity (nearly 90% from the initial condition) greatly reduces the burden on the community in preparing water for daily use. However, routine laboratory testing is still necessary to monitor water quality, particularly during the rainy season. Capacity building for the water management group remains essential—not only to operate and maintain the filter system but also to educate residents about the need for further household-level treatment before drinking.

4 Conclusion

The implementation of a natural filtration system using locally available materials such as pumice stone and activated carbon has successfully improved water quality in Semaja Village, particularly addressing the deterioration of water quality during the rainy season. This system significantly reduced key pollutant parameters, including Chemical Oxygen Demand (COD), iron concentration, Total Dissolved Solids (TDS), and Biological Oxygen Demand (BOD). Therefore, the natural filtration approach provides a sustainable and effective solution to meet the clean water needs of the Semaja community, contributing to the health and well-being of its residents.

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