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Integrating Appropriate Technology for River Water Purification at Darul Qur'an Al-Hanif Islamic Boarding School, Banyuasin Regency, Indonesia

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Abstract: River water often contains a complex mixture of organic and inorganic contaminants that are challenging to remove using conventional treatment methods. This study explores an integrated water purification system combining large-pore activated carbon, polyester fiber filters, and ultrafiltration membranes. Activated carbon demonstrates high affinity for a wide range of pollutants, effectively reducing odor, color, and both organic and inorganic impurities, while also contributing to pH enhancement and reductions in Total Dissolved Solids (TDS) and Total Suspended Solids (TSS). Polyester fiber filters offer high filtration efficiency, mechanical durability, ease of maintenance, and adaptability, making them suitable as a secondary filtration layer to capture fine particulates not removed by activated carbon. Additionally, the use of ultrafiltration membranes with pore sizes of 0.5 mm, 0.3 mm, and 0.1 mm ensures the removal of residual dissolved and suspended solids. The integration of these three technologies is expected to produce clean water that meets Class 1 water quality standards. The system is user-friendly and features a backwashing mechanism, enhancing ease of operation and maintenance.

Keywords: River water treatment; Activated carbon; Polyester fiber filter; Ultrafiltration membrane; Water purification technology

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1. INTRODUCTION

Water is a vital natural resource essential for human life. However, rivers in many regions are frequently polluted due to various factors, including industrial, agricultural, and urban waste. One common issue is the decrease in river water pH, which is often caused by acidic waste from industrial and mining activities. Low pH levels not only have adverse effects on the environment but can also pose serious health risks if the water is used for domestic purposes without proper treatment (Akhtar et al., 20231. This community engagement initiative aims to improve the quality of water from the Jalur 19 River, transforming it into clean and safe water for cooking, washing, and other household uses, in accordance with Class I water quality standards as stipulated in Government Regulation No. 22 of 2021. The broader objective is to reduce health risks associated with the consumption of contaminated river water, mitigate the negative environmental impacts on the river ecosystem and surrounding biodiversity, and contribute positively to sustainable development and the well-being of the local community (Ejiohuo et al., 2025).

1.1 Situational Analysis

Darul Qur'an Islamic Boarding School is located in Suka Damai Village, Jalur 19, Tanjung Lago District, Banyuasin Regency. Astronomically, Suka Damai Village is situated at 104°43'52.7'' E and 02°43'16.1'' S, covering a total area of 1,600 hectares. Administratively, it is one of the villages within the Tanjung Lago District, Banyuasin Regency, South Sumatra Province.

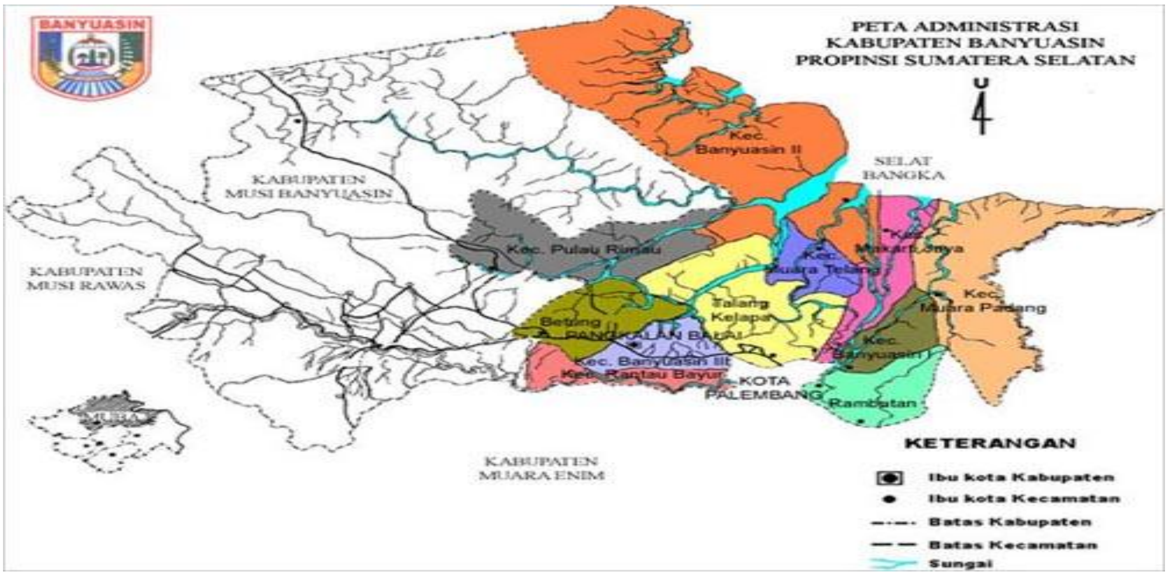

Figure 1. Community Service Activity Location Map

Suka Damai Village is located approximately 35 kilometers from the center of Palembang City. The village is square in shape, covering an area of 4 km × 4 km, equivalent to 1,600 hectares. Residential areas are evenly distributed and interspersed with oil palm plantations. Each residential plot typically covers 0.25 hectares, consisting of a house and a yard. Land use in Suka Damai is diverse, including residential areas, local markets, rice and secondary crop fields, vegetable and fruit gardens, as well as rubber and oil palm plantations. Notably, the village still maintains approximately 232 hectares of rice fields.

Suka Damai is well-equipped with religious facilities, including mosques, prayer halls (mushola), and churches. The village also has one community health center (puskesmas) and two maternity clinics. In terms of education, Suka Damai has developed facilities ranging from early childhood education (PAUD) to senior high school (SMA). Recreational facilities include 10 volleyball or tennis courts and soccer fields, as well as two buildings designated for cultural and artistic activities. Additionally, there are two cooperative buildings that serve as partners in the oil palm plantation sector, and a modest village office building. According to the 2013 demographic data, Suka Damai consists of four hamlets (dusun) and 19 neighborhood units (RT), with a total of 846 households. Most of the residents are transmigrants from Java Island, and as a result, Javanese is the predominant language spoken in the village. Given the land use, the majority of the population are farmers, with agriculture and plantation work serving as the primary sources of livelihood.

1.2 Issues and Proposed Solutions

The primary source of raw water for domestic use in Suka Damai Village is the Jalur 19 River, a distributary of the Musi River that flows through several villages in the Tanjung Lago District. The Darul Qur'an Islamic Boarding School also relies on this river—located to the west of the pesantren—for its daily water needs. Observations conducted at the site revealed that the river water has a relatively acidic pH level, making it unsuitable as a source of clean water. The water has a slightly bitter taste and exhibits seasonal variation in both quality and quantity. During the dry season, the water level significantly decreases, and its acidity increases. In contrast, during the rainy season, the water becomes turbid, with pH levels ranging between 5 and 6. Therefore, a proper water treatment process is necessary to convert this river water into clean water that is safe for household uses such as cooking, drinking, bathing, and other daily activities (Das, 2025).

Figure 2. Location of Service and River Water as Raw Materials

The treatment of river water with low pH into clean and safe water for domestic use has become an urgent necessity. Through this community service initiative, we aim to implement an effective and efficient water treatment method to increase the pH level of the river water, thus producing clean water that is safe for daily use by the local community. This will be achieved by applying appropriate technology that has been tested in laboratory settings and is ready for community-level implementation (Amin et al., 2024).

1.3 Physical Requirements of Clean Water

According to Rolia et al (2023), clean water must be clear, odorless, and tasteless. Additionally, its temperature should ideally match ambient air temperature—around 25°C—with an acceptable range of 25°C ± 3°C. The maximum permissible turbidity is 25 NTU, and the maximum color level is 50 TCU. Turbidity is an optical effect caused by suspended particles in water. It is often the result of organic and inorganic materials such as silt or waste from various surfaces that make river water appear cloudy. Even slight turbidity can alter the apparent color of water. Highly turbid water poses challenges in treatment, particularly in filtration and disinfection processes, as it interferes with the effectiveness of microbial removal. Turbidity levels are closely related to pH, and clean drinking water is typically treated to be as clear as possible (Umar, 2022).

Odor in water can be caused by foreign substances such as animal carcasses, waste, or the decomposition of organic compounds by bacteria. This bacterial activity can release foul-smelling and sometimes toxic gases. The decomposition process also increases the biological oxygen demand (BOD), thereby reducing the dissolved oxygen (DO) content in water. Odor detection is typically conducted using the human sense of smell to determine the presence of contaminants. If water has an unpleasant odor, it is deemed unsuitable for consumption (Aguilar-Torrejón et al., 2023). The taste of raw water may be influenced by the presence of organisms like microalgae and bacteria, solid and liquid waste (e.g., from household runoff), and residual disinfectants such as chlorine. Taste issues often correlate with odor problems. Drinking water is expected to have a neutral and acceptable taste. Sensory evaluation using the human palate is used to identify deviations from the neutral standard, ensuring the water is palatable and safe (Adams et al., 2022).

For Chemical Requirements, clean water must not contain chemical substances exceeding permissible limits. Some key chemical parameters include pH levels between 6.5 and 9.0, total dissolved solids (TDS), organic matter, aggressive CO_2, water hardness, calcium (Ca), iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), chloride (Cl), nitrite, fluoride (F), and heavy metals. These elements must be monitored and controlled to meet safe water quality standards (Salehi, 2022).

Meanwhile for Bacteriological Requirements, Bacteria are a crucial group of microorganisms in water treatment. They are colorless, single-celled organisms that reproduce rapidly—every 15 to 30 minutes—under ideal conditions. Bacteria survive by utilizing dissolved nutrients in water. While many bacteria are beneficial in decomposing organic matter and stabilizing waste, pathogenic bacteria such as Escherichia coli (E. coli)—a coliform bacteria—are used as indicators of drinking water contamination and quality. Viruses are not fully living organisms and are considerably smaller than bacteria, ranging from 20 to 100 nanometers—about 1/50 the size of a bacterium. In drinking water, viruses are a major public health concern, as even a single viral particle can cause infection. They often enter water sources through fecal contamination and can become a significant source of disease transmission if not properly treated (Trinh & Lee, 2022).

2 LITERATURE REVIEW

2.1 Integration of Filter Media for Filtration and Adsorption

Filtration is the process of separating suspended solid components in water by passing the water through a porous medium or other filtering material to remove suspended and colloidal solids. Porous media can adsorb fine particles originating from both organic and inorganic compounds, while suspended solids settle and accumulate on the upper layer of the filter medium. Due to its high adsorption efficiency, porous media such as activated carbon are widely used in water and wastewater treatment. Filtration can also reduce the presence of bacteria, odor, taste, manganese, and iron (García-Ávila et al., 2021). According to Cescon & Jiang (2020), if the raw water treatment process does not require coagulation, the water can be directly filtered using various types of filtering media, porous or non-porous. The filtration characteristics are expressed by the filtrate flow rate. The selection of filtering media is based on technical and economic considerations with the main goal of producing affordable filtrate of consistently high quality.

2.2 Activated Carbon Adsorbent

Water treatment using activated carbon as an adsorbent is a highly effective method for removing various organic and inorganic contaminants from water, including dyes, odors, tastes, pesticides, heavy metals, and potentially harmful organic compounds. The effectiveness of this method is influenced by several factors: such as (a) Activated carbon has a highly complex pore structure and a large surface area, enabling it to adsorb a substantial amount of dissolved substances; (b) It exhibits strong adsorption properties for a wide range of organic and inorganic molecules through van der Waals forces or chemical interactions; (c) Particle size affects its performance—powdered or granular activated carbon is typically more effective than solid blocks; (d) Factors such as contact time, temperature, pH, and contaminant concentration significantly influence adsorption efficiency. Optimal operational conditions enhance performance; (e) Saturated activated carbon can be regenerated using chemical washing or thermal processes, reducing operational costs; (f) It demonstrates selectivity for specific substances, depending on their physical and chemical properties, allowing for targeted contaminant removal; and (g) Adsorption capacity may be limited at high contaminant concentrations, necessitating more frequent replacement or regeneration (Khan et al., 2023).

2.3 Filter Media with Polyester Fiber

Filters using polyester fiber media are commonly applied in various filtration systems, including water treatment. Polyester fiber (serpol) is durable, lightweight, and versatile. It functions as an effective physical barrier, capturing fine to medium particles such as sand, silt, and other debris. These filters have fine fibers capable of trapping small to medium particles, making them ideal for preliminary filtration stages. They are also chemically resistant to substances like chlorine and mild acids or bases, maintaining performance across diverse water conditions. Additionally, polyester fiber can be washed and reused, making it a cost-effective long-term solution (Zhang et al., 2023).

Compared to other filter media, polyester fiber is physically robust and resistant to tearing under pressure or heavy flow. Its lightweight and flexible nature allows it to be adapted to various filter designs, from cartridge filters to large-scale industrial systems. Its reusability also reduces disposable filter waste, and its structural integrity is maintained over time, ensuring consistent filtration quality. Applications of Polyester Fiber Media Include: (a) Household Water Treatment Systems; (b) Aquariums and Ponds; (c) Large-Scale Water Treatment Systems; and (d) Textile and Food Industries (Beckman et al., 2023).

Due to its structural performance and consistent results, polyester fiber is a practical and economical solution for water filtration in both domestic and industrial contexts. Given the benefits of activated carbon and polyester fiber media, the Appropriate Technology being developed for river water treatment will integrate both technologies, followed by an ultrafiltration process to produce clean water that meets the Indonesian National Standard (SNI). In this integrated process, water flows through the filter media in a meandering pattern, following the internal pores and surface layers of the media. This creates velocity gradients that promote interactions among fine particles, allowing them to form larger aggregates that can be trapped deeper within the filter, resulting in filtrate that meets clean water standards. As the filtration progresses, contaminants accumulate on the filter surface, eventually clogging the media. Once clogged, the filter's permeability decreases significantly, and the flow rate drops, with excess water diverting through an overflow channel. This indicates that the medium requires cleaning. A backwashing process must be performed to restore the filter's function and allow for reuse (Soffian et al., 2022).

2.4 Application of Microfiltration and Ultrafiltration Membranes

The application of microfiltration and ultrafiltration membranes in wastewater treatment is widely accepted for their ability to consistently produce high-quality effluent while recovering valuable components for reuse or resale. Microfiltration is a pressure-driven membrane process that retains suspended colloids and particles sized 0.1–20 µm. It operates at relatively low transmembrane pressure (<50 psi or 3.4 bar or 0.35 MPa) and offers high permeate flux (10^{-4}–10^{-2} m/s under non-fouling conditions) (Scott, 1995). Microfiltration membranes are asymmetric, with thicknesses of 10–150 µm and pore sizes between 0.05–10 µm. The permissible pressure differential is <2 bar (Hakami et al., 2020).

Ultrafiltration (UF) membranes bridge the gap between microfiltration and nanofiltration. They typically have pore sizes ranging from 0.05 µm (closer to microfiltration) down to 1 nm (closer to nanofiltration). While dissolved salts and small molecules pass through, larger substances such as colloids, proteins, microbiological contaminants, and large organic molecules are retained. UF membranes yield two outputs: permeate (containing small molecules) and retentate (containing retained solids) (Mulder, 1996). In clean water production, ultrafiltration uses semipermeable membranes to filter colloids, turbidity, suspended solids, bacteria, and molecules sized between 0.1–0.01 µm. This technique replaces conventional filtration processes like clarifiers, offering advantages such as compact design, eliminating the need for chemical additives (e.g., coagulants, flocculants, biocides, and pH regulators), and reducing the footprint of the treatment system. Commercial UF systems currently offer capacities ranging from 500 to 6,000 liters per membrane unit. The primary function of UF membranes is to remove Total Suspended Solids (TSS), with removal efficiencies of up to 99% when properly designed and implemented (Castro & Abejón, 2024).

Working Mechanism of UF (0.01 µm): Water enters at low pressure (~1.5 bar) through fine inlet pores (0.5–2 mm). The UF membrane's pores (0.01–0.05 µm) are much smaller than the diameter of a human hair (~50 µm), allowing it to reject contaminants larger than the pore size. These contaminants are periodically flushed out via backwashing or forward flushing. A key advantage of UF membranes is their absolute pore rating, offering superior sterility compared to conventional filters, especially in microbial removal (Peter-Varbanets et al., 2011).

3. METHOD

3.1 Implementation Method of Community Service

The solution to the clean water problem at Darul Qur'an Islamic Boarding School, located in Sukadamai Village, Banyuasin Regency, involves the provision of appropriate technology (AT) for the treatment of water from the Jalur 19 River in Sukadamai. As most environmental parameters of the river water exceed the permissible quality standards for daily human consumption, the river water must be treated before use. The implementation stages are as follows: (1) Survey and analysis of river conditions, including the identification of potential pollution sources; (2) Development of water treatment methods, including the selection of suitable materials and appropriate technology; (3) Field trials to validate laboratory results and evaluate the performance of the treatment methods at a larger scale.

The Appropriate Technology (AT) employed for river water treatment integrates three processes: adsorption, filtration, and ultrafiltration. Prior to these processes, a pretreatment stage involving sedimentation is carried out. The sequential process steps are as follows:

1. Sedimentation Process

At the initial stage, river water is subjected to sedimentation inside a 1,500-liter water tank. This allows fine particulate matter to settle at the bottom. After sedimentation, the clarified water is channeled to the next treatment stage through the pre-installed AT system.

2. Adsorption Process

The adsorption stage uses activated carbon derived from coconut shell charcoal as the adsorbent. The activated carbon, sized 3–5 mm, is filled into a cylindrical PVC tube with a diameter of 4 inches and a height of 60 cm. A 30 cm layer of activated carbon is placed inside the tube, followed by a polyester filter layer on top. Two identical adsorption columns are used and operated in parallel.

3. Filtration Process

A polyester fiber filter placed above the activated carbon serves to further enhance water quality. This layer is especially effective in removing suspended organic and inorganic particles from the water.

Figure 3. Design of Appropriate Technology Tools for Processing River Water into Clean Water

The use of ultrafiltration (UF) in water treatment is a highly effective method for removing fine particles, bacteria, viruses, and dissolved organic substances from water. This process produces water that is safe to drink without the need for chemical additives such as chlorine. Moreover, ultrafiltration systems can be easily integrated into existing water treatment setups or operated independently, making them highly flexible and adaptable to a wide range of applications—from household-scale systems to large-scale water treatment for communities or industries. The integrated Appropriate Technology (AT) equipment for processing water from the Jalur 19 River is illustrated in Figure 3.

3.2 Water Treatment Process Stages

The treatment process begins by pumping river water to a storage tank located on the second floor. From there, water is released through a faucet and flows by gravity into the treatment equipment through a central pipe. The water is then directed to both the left and right sides, rising into two adsorption columns via an up-flow system, passing through a layer of activated carbon adsorbent and polyester fiber filter. The retention time of the flow is controlled using pre-installed valves. Next, the water flows into the ultrafiltration unit, where the flow rate is adjusted using valves installed on either side of the adsorber columns. The treated water is then collected in a product tank. A backwash process is conducted by closing the valve on one side of the adsorber column, allowing water to flow in reverse from the opposite side and out through the designated outlet. This procedure is then repeated for the other column. The backwash process ensures that the adsorbent remains clean, thus prolonging the operational lifespan of the media and maintaining system efficiency over time (Widianingsih et al., 2020).

4. RESULTS AND DISCUSSION

4.1 Results

The trial implementation of the Appropriate Technology (AT) system was conducted on September 18, 2024, at the Darul Qur'an Al-Hanif Islamic Boarding School located in Suka Damai Village, Tanjung Api-Api, Tanjung Lago Sub-district, Banyuasin Regency. The event was attended by the head of the boarding school, teachers (ustadz and ustadzah), students, the village secretary, the head of the Office of Religious Affairs (KUA), parents of the students, and local community members around the boarding school.

Table 1. Analysis Results of Water Quality from River Water Treatment Process

	pH	**EC**	**TDS**	**TSS**
Raw Material from River Water Route 9	4,25	2844	2747	255
Activated Carbon + Polyester Fiber Filter	6,17	2007 (Eff. 29,43%)	999 (Eff. 63,63%)	44 (Eff. 82,47%)
Ultra Filter	8,21	1983 (Eff. 30,27%)	987 (Eff. 64,07%)	33 (Eff. 87,5%)
Clean Water Quality Standards (Class 1) Government Regulation No. 22 of 2021	6-9	-	1000	40

Based on the analysis of river water that has undergone treatment using adsorption and filtration methods, the resulting clean water meets Class 1 clean water quality standards for the parameters of pH, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), and Electrical Conductivity (EC). There is a strong correlation between EC and TDS. Water with high EC typically has high TDS, indicating a significant concentration of dissolved ions. The analysis shows that TDS was reduced by 63.63% and EC by 29.43% through the adsorption process. When integrated with ultrafiltration, the reduction efficiency increased slightly, reaching 64.07% for TDS and 30.27% for EC.

The river water's highly acidic pH was effectively increased through this treatment technology. The activated carbon adsorbent was able to increase the pH from 4.25 to 6.17, and when combined with ultrafiltration, the pH further increased to 8.21. It is known that pH measures the concentration of hydrogen ions (H^+) in water; while pH is not directly proportional to EC, changes in pH are often accompanied by changes in other ion concentrations that can influence conductivity. The TSS level in the untreated river water was 255 mg/L. Through this treatment process, TSS was reduced with an efficiency of 82.47%, indicating that activated carbon adsorbents, due to their porous nature, are capable of trapping undissolved solid particles in water. While these suspended particles do not directly contribute to electrical conductivity—since they are not dissolved ions—some may degrade or react in water to produce ions that increase conductivity.

4.2 Discussion

The implementation of an Appropriate Technology (AT) system for river water treatment at the Darul Qur'an Al-Hanif Islamic Boarding School in Suka Damai Village, Indonesia, has demonstrated significant improvements in water quality. The treatment process, which combines sedimentation, adsorption using activated carbon, filtration with polyester fibers, and ultrafiltration, effectively reduced contaminants such as Total Dissolved Solids (TDS), Total Suspended Solids (TSS), and adjusted pH levels to meet Class 1 clean water standards as per Indonesian regulations. The integration of these methods aligns with sustainable water treatment practices, ensuring the provision of safe and clean water for the community (Azanaw et al., 2022).

Activated carbon derived from coconut shells was utilized for its high adsorption capacity. This material effectively removed dissolved solids and improved water clarity. Studies have shown that activated carbon from various biomass sources, including walnut shells, bagasse, and rice husks, can efficiently reduce TSS, TDS, and other pollutants in wastewater. The integration of ultrafiltration further enhanced the removal of fine particles and pathogens, ensuring the production of safe drinking water. Ultrafiltration membranes are known for their ability to remove suspended solids and solutes of high molecular weight, making them suitable for producing high-quality effluent (Jjagwe et al., 2021).

The combined treatment approach not only improved water quality but also proved to be cost-effective and environmentally friendly. The use of locally available materials for activated carbon production and the minimal requirement for chemical additives make this system sustainable for rural communities. Moreover, the simplicity of the system's operation allows for easy adoption and maintenance by local residents. This aligns with the findings of previous studies that emphasize the importance of community involvement and the utilization of local resources in water treatment initiatives (Diallo et al., 2024).

The success of this project serves as a model for similar interventions in other regions facing challenges with water contamination. By leveraging locally sourced materials and straightforward technologies, communities can achieve significant improvements in water safety and public health. The integration of traditional and modern water treatment methods addresses both the technical and socio-economic aspects of water management, ensuring the sustainability and scalability of such initiatives (Singh et al., 2023).

Furthermore, the implementation of this AT system contributes to the broader goals of environmental conservation and sustainable development. By reducing reliance on chemical treatments and promoting the use of renewable resources, the project aligns with global efforts to mitigate environmental degradation and promote sustainable water management practices. The project's emphasis on education and community engagement also fosters a culture of environmental stewardship and empowers individuals to take an active role in preserving their natural resources (Kamran et al., 2024).

In conclusion, the AT system implemented at the Darul Qur'an Al-Hanif Islamic Boarding School demonstrates the effectiveness of combining traditional knowledge with modern technology to address water quality challenges in rural communities. The project's success underscores the importance of community involvement, the utilization of local resources, and the integration of sustainable practices in water treatment initiatives. Future efforts should focus on scaling up such interventions and conducting further research to optimize the system's efficiency and adaptability to different environmental contexts.

4.3 Evaluation

The evaluation of the activity was conducted by distributing questionnaires to participants in order to assess their level of understanding of the materials presented, identify any shortcomings, and gather suggestions for future activities. The results of this questionnaire-based evaluation serve as a reference for improving similar community engagement activities in the future. The questionnaire was distributed to 35 students and 8 teachers, and the results are presented in Table 4.2. The findings indicate that this community service activity should be continued and expanded, particularly for communities in need of river water treatment technologies to meet their daily domestic water needs.

Table 2. Evaluation Results

No	Question	Yes (%)	No (%)	Not Sure (%)
1	Is the river water in this village used for bathing, washing, and cooking purposes?	100	-	-
2	If yes, are you aware that the river water being used does not meet the clean water health standards?	90	8	2
3	If yes, have you implemented any filtration methods?	2	96	2
4	If not, do you think that socialization on river water treatment into clean water for daily needs is necessary?	100	-	-
5	Was the explanation/presentation of the topic delivered by the team easy to understand for you and the students?	98	2	-
6	Did the appropriate technology for river water treatment presented by the FT-Unsri team bring benefits to the participants because its product is very useful for human life?	99	-	1
7	Do you think the appropriate technology for river water treatment is easy to practice and operate?	96	-	4
8	Are the participants open to future Community Service Programs by the Sriwijaya University team? If yes, please write your suggestions for the next community service theme in the available column	100 (Ya)		

Most members of the local community still use river water directly without any treatment, as indicated by the questionnaire results. Only 2% of the respondents (students and local residents) reported making any effort to filter river water before use, while the remaining 98% use it directly for cooking, bathing, and washing. For drinking purposes, they rely on refillable bottled water. Through this community service activity and the socialization of simple, easy-to-operate water treatment technology, it is expected that a practical solution will be introduced to address the poor water quality of the Jalur 9 river, which currently does not meet the clean water quality standards. This initiative is aimed at fulfilling the daily domestic water needs of both the Islamic boarding school and the surrounding residents. Furthermore, the introduced technology is designed to be easily constructed and operated, making it a replicable and sustainable model that local communities can adopt and implement independently.

5. CONCLUSION

The implementation of the integrated Appropriate Technology (AT) system—comprising sedimentation, adsorption with activated carbon, polyester fiber filtration, and ultrafiltration—has proven to be highly effective in improving the quality of river water from Jalur 9 in Suka Damai Village. The treatment process significantly reduced key parameters such as Total Dissolved Solids (TDS), Total Suspended Solids (TSS), and Electrical Conductivity (EC), while successfully increasing the pH level to meet the Class 1 clean water standards as regulated in Government Regulation No.

22 of 2021. These findings demonstrate that a combination of physical treatment and advanced membrane filtration technologies can produce safe, clean water for domestic use without the need for chemical additives, making it an environmentally friendly and sustainable solution.

Beyond the technical success, the program had a positive impact on raising awareness among the local community and students about the importance of water treatment prior to use. The active participation of local stakeholders—including religious leaders, teachers, and residents—contributed significantly to the program's success and sustainability. The technology is simple to operate and maintain, making it highly replicable in other rural areas facing similar challenges with water quality. Moving forward, long-term evaluation and policy support will be essential to scale up this solution as a systemic approach to addressing clean water access in underserved regions.

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