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Innovation Compact System Usage for Household Water Treatment: A Case Study on Water Quality in Coastal Central Java

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ABSTRACT

In many coastal regions of Central Java, Indonesia, access to safe drinking water remains limited owing to often contaminated groundwater sources. This study evaluated the performance of a compact household water treatment system integrating aeration, filtration, adsorption, and ultraviolet (UV) disinfection. Water samples from 15 wells across Kendal, Semarang, and Demak were tested for 13 parameters, including turbidity, total dissolved solids (TDS), color, ammonia, iron, manganese, dissolved oxygen (DO), and total coliforms, analyzed by ISO/IEC 17025-accredited laboratories. The treatment significantly improved water quality, reducing turbidity from 14.00 to 4.96 NTU (65%), TDS from 738.6 to 336.35 mg/L (54%), color from 21.93 to 9.15 TCU (58%), and ammonia from 1.82 to 1.02 mg/L (44%); meanwhile, DO increased from 5.48 to 8.24 mg/L (33%). The Drinking Water Quality Index scores of samples from 80% of the sites improved from "very poor" (>200) to "good" (<100), indicating untreated water transformation from non-potable to potable. However, microbiological safety remained a limitation, with total coliforms reduced by 52% (from 230 to 110 CFU/100 mL) but failing to meet the 0 CFU/100 mL standard. Therefore, additional heat treatment or UV contact time extension from 3 to 6 h is recommended to achieve full microbial compliance. This study demonstrates the effectiveness of the treatment system in significantly improving physical and chemical quality, while highlighting the need to optimize its microbial disinfection capacity. Its affordability and simplicity make it a promising decentralized solution for underserved communities.

HIGHLIGHTS

- Compact system integrates aeration, filtration, adsorption, and UV.
- Turbidity, TDS, and ammonia reduced by over 40-60% across samples.
- Simple, affordable system fits household use in coastal communities.

1. INTRODUCTION

Access to clean water is fundamental to human health, well-being, and socioeconomic development (Amorocho-Daza et al., 2023). The basic water requirement per person ranges from several to tens of liters per day (Annobil, 2021). According to the World Health Organization (2022), a minimum of 20 L/capita/day is required to meet drinking, cooking, and hygiene requirements. Although survival-level drinking water needs are estimated at approximately 2.5 to 3 L/person/day, the WHO recommends an intermediate access threshold of approximately 50 L/person/day to adequately support public health and sanitation. These benchmarks highlight the importance of ensuring sufficient water quantity and quality for human use, especially in areas with limited infrastructure.

In Indonesia, the national water supply system is heavily dependent on non-piped sources. Although approximately 90% of the population has access to some form of improved water source, only about 19% of households are connected to municipal piped networks (PDAM) (Firdaus et al., 2024). Many households still rely on groundwater from wells and

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springs, harvested rainwater, or commercially packaged water. Bottled and refill station water consumption has increased significantly in recent years, with forecasts suggesting that by 2026, nearly half of Indonesia's population will rely on packaged drinking water (Zikrina et al., 2024). Conversely, only approximately 9% of the population uses PDAM water for drinking, despite system coverage reaching approximately 35% of the national territory. This discrepancy is largely attributed to concerns about service reliability, water safety, and infrastructure limitations, particularly in rural and peri-urban areas (Cronin et al., 2017; Firdaus et al., 2024).

Historically, groundwater and spring water sources in Indonesia have been considered safe. However, rapid environmental degradation, pollution, and adverse geochemical conditions have contributed to the contamination of many sources (Basuki et al., 2024). In particular, coastal aquifers in northern Java are frequently affected by saline intrusion and reductive conditions that mobilize metals such as iron and manganese. In Indramayu, groundwater commonly exhibits elevated levels of these metals, surpassing the national drinking water standards. Indonesian regulations require drinking water to meet stringent physical, chemical, microbiological, and radiological quality requirements (Rusydi et al., 2021). Failure to comply with these standards due to the presence of pathogens, excessive metals, or high turbidity poses serious health risks in practice. Households that lack access to safe piped water often resort to boiling or purchasing refill water as a mitigation strategy (Bashir et al., 2020).

Water quality degradation is particularly severe in the coastal regions of Central Java. For example, Semarang has experienced ongoing groundwater salinization and increased pollution pressures (Rahmawati and Marfai, 2013). Despite being a provincial capital, only approximately 8% of the residents consume PDAM water directly, with a larger proportion (approximately 26%) depending on water from refill stations, which are treated but often not subject to the same level of regulatory oversight. Piped services are often nonexistent in rural and peri-urban areas (USAID, 2023). The widespread reliance on packaged water has also created substantial environmental burdens. Recent sustainability assessments have estimated that packaged water consumption in Java contributes to the annual production of millions of tons of plastic waste.

The combination of saline and contaminated groundwater, limited piped-water infrastructure, and increasing dependence on expensive packaged water present a complex challenge for coastal Central Java, which needs affordable, household-level water treatment technologies that can improve water quality at the point of use. This study introduces the Innovation Compact System, a small-scale integrated treatment solution that combines multiple purification processes to transform well water and groundwater into potable water compliant with Indonesian national standards, removing the need for boiling. By enabling the local treatment of non-piped sources, this technology offers a cost-effective alternative to packaged water, potentially reducing household expenses, minimizing environmental waste, and improving health outcomes in underserved communities.

2. METHODOLOGY

2.1 Materials and tools

This study used gravel, silica sand, white sponges, biofoams, and tools such as glass and stainless steel casings, separators, connectors, pumps, burrs, drills, and ultraviolet (UV) lamps. Sterile bottles were used for microbiological sampling, and a 5 L high-density polyethylene (HDPE) jerry can was employed as a sterile container to preserve the integrity of collected samples. All physicochemical and microbiological analyses were performed using standardized ISO methods in ISO/IEC 17025-accredited laboratories.

2.2 Research design

The Innovation Compact System for water treatment (Figure 1) was engineered by incorporating key mechanisms, specifically aeration, filtration, adsorption, and disinfection. Aeration enhances the dissolved oxygen (DO) concentration and eliminates dissolved gases, including hydrogen sulfide. Filtering is conducted using media such as activated carbon to eliminate solid particles and diminish turbidity, color, and odor. Adsorption promotes the binding of both organic and inorganic contaminants to the adsorbent surface. UV light disinfection can effectively eliminate harmful microorganisms and simultaneously maintain the essential mineral content of water. Integrating these four processes into a single system is a practical and efficient solution for improving drinking water quality.

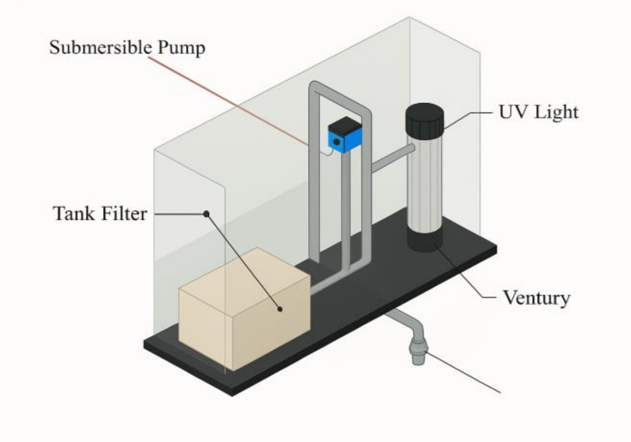

Figure 1. Compact drinking water treatment system design

The treatment system, with a capacity of 5 L, was carefully developed to prioritize users and operational efficiency. Untreated water was inserted into the system by a physical filter unit comprising various layered materials, such as silicon dandals and other selected media, specifically developed to remove suspended solids and reduce haze. The water was then moved by pumps built through the system to initiate a ventilation process to improve the DO content and remove volatile compounds. Subsequently, the treated water was exposed to UV rays for 3 h to remove pathogenic bacteria and ensure thorough disinfection. This comprehensive process ensured that the resulting water met the strict quality standards and was safe and suitable for drinking.

2.3 Sampling

The samples were collected using grab sampling. Sterile equipment was employed for microbiological examination, and physical and chemical analyses were performed on water samples gathered in a 5 L jerry can. Careful handling was performed to prevent oxygen bubbles from entering the container. The number of samples collected was calculated using Equation 1:

$$(t-1)(r-1) \geq 15 \quad (1)$$

Where; t refers to number of treatments, which is 2 (1 control and 1 device), and r is the number of replications, which was determined to be 15 using the formula.

Water quality sampling was conducted across three coastal regions in Central Java: Kendal City, Semarang City, and Demak Regency. Fifteen sampling sites were selected to capture a range of environmental and residential conditions: Peggagayam (Neighborhood Unit 3 / Community Unit 9), Gayaman (Neighborhood Units 1, 2, and 3 / Community Unit 2), East Tugurejo (Neighborhood Units 4, 5, and 6 / Community Unit 5), Jrakah (Neighborhood Units 1 and 4 / Community Unit 3), Dempel (Neighborhood Unit 2 / Community Unit 2), with three samples taken from different points, Jati Utara (Neighborhood Unit 2 / Community Unit 3), and Krajan (Neighborhood Unit 3 / Community Unit 4) (Figure 2).

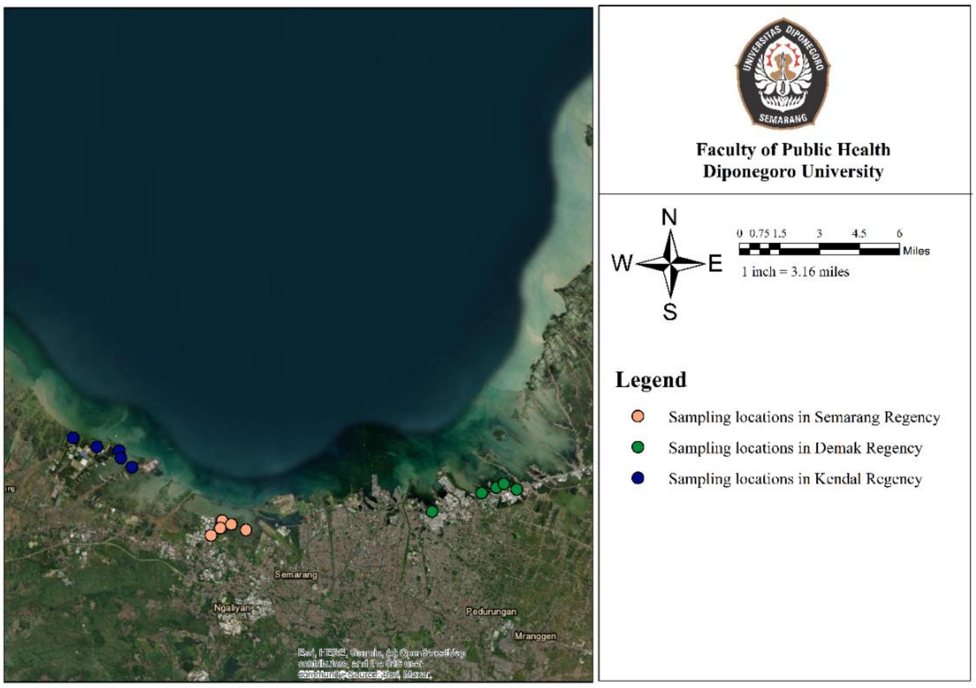

Figure 2. Sampling locations in the selected coastal regions

2.4 Water quality assessment

The Drinking Water Quality Index (DWQI) was assessed using the weighted arithmetic index method, which remains a widely adopted approach for quantifying the overall water quality suitability for human consumption. Each physicochemical and microbiological parameter was assigned a unit weight (Wi), reflecting its relative importance to public health and environmental risks. The weight values were determined with reference to the WHO Guidelines for Drinking Water Quality (4th edition, 2008) and adjusted to align with the national standards stipulated in the Regulation No. 492/Menkes/Per/IV/2010 (Ministry of Health of the Republic of Indonesia, 2010; World Health Organization, 2022).

Parameters with high toxicological and pathogenic significance such as lead, nitrite (NO_2^-), and total coliform bacteria, were assigned higher Wi values (≥0.08) to acknowledge their potential to cause acute and chronic health effects even at low concentrations. Conversely, parameters considered mainly aesthetic or non-toxic, such as color, temperature, and alkalinity, were assigned lower Wi (≤0.03). This weighting approach follows established protocols adopted in water quality studies diverse geographical settings (Table 1) (Şener et al., 2017; Solangi et al., 2020; Yilikal et al., 2018).

The DWQI computation involved four steps. First, a quality rating (qi) for each parameter was calculated using Equation 2:

$$qi = \left(\frac{C_i}{S_i}\right) \times 100 \quad (2)$$

Where; CiC_iCi is the measured concentration of the iii-th parameter and SiS_iSi is the corresponding permissible limit according to WHO or Permenkes 492. Second, the sub-index (SIi) was derived as follows:

$$SI_i = W_i \times q_I \quad (3)$$

Finally, the DWQI value for each sample was obtained by summing the sub-indices:

$$DWQI = \sum_{i=1}^{n} SI_i \quad (4)$$

Table 1. DWQI parameter weights (Wi) and standard values (Si)

Parameter	Unit	Standard value (S_i)*	Weight (W_i)	Justification**
Turbidity	NTU	<5	0.05	Aesthetic concern, may indicate pathogens
Temperature	°C	±25	0.03	Minimal health impact
TDS	mg/L	<500	0.05	Affects palatability
Color	TCU	<15	0.04	Aesthetic parameter
Alkalinity	mg/L	-	0.02	No direct toxicity
Ammonia	mg/L	<1.5	0.08	Indicates pollution, toxic at high levels
Iron	mg/L	<0.3	0.08	Can affect organs, high levels dangerous
Hardness	mg/L	<500	0.05	Related to Ca and Mg, not toxic
Manganese	mg/L	<0.4	0.05	Affects nervous system at high doses
DO	mg/L	-	0.1	Indicates water freshness, aquatic life
pH	-	6.5-8.5	0.1	Influences solubility of toxic elements
Lead	mg/L	<0.01	0.15	Highly toxic, neurotoxin
Organic substances	mg/L	<10	0.05	Reflects organic pollution load
Total coliform	CFU/100 mL	0	0.15	Indicator of fecal contamination

*Si values (Ministry of Health of the Republic of Indonesia, 2010; World Health Organization, 2022).
**Justifications (Şener et al., 2017; Solangi et al., 2020; Yilikal et al., 2018).

The final DWQI values obtained for each water sample were interpreted using a standard classification scheme (Şener et al., 2017; Solangi et al., 2020; Yilikal et al., 2018) that categorizes water quality into five distinct levels ranging from "excellent" to "unsuitable for drinking purposes" based on the cumulative score derived from all analyzed parameters. The interpretation framework used in this study is summarized in Table 2.

2.5 Data analysis

Statistical analysis was conducted using IBM SPSS Statistics version 23 to evaluate the household water treatment system effectiveness based on DWQI changes. Descriptive analysis was performed to summarize the DWQI scores before and after treatment. The Shapiro-Wilk test was used to assess data normality. Depending on the distribution, either a paired sample t-test or Wilcoxon signed-rank test was used to determine whether the post-treatment DWQI differed significantly from the pre-treatment values. A p-value <0.05 was considered statistically significant. This study aims to assess the overall improvement in drinking water quality resulting from the application of the compact treatment system.

Table 2. Interpretation of the DWQI results

DWQI range	Water quality category	Interpretation
<50	Excellent	Suitable for drinking without treatment
50-100	Good	Acceptable, may need minor treatment
100-200	Poor	Not recommended without treatment
200-300	Very poor	Strong treatment required before consumption
>300	Unsuitable	Not fit for drinking under any circumstance

Adapted from: (Mohammad et al., 2024; Şener et al., 2017; World Health Organization, 2022)

3. RESULTS AND DISCUSSION

3.1 Comparative water quality assessment

Table 3 shows the average water quality parameter values before and after using the compact filter device to clean the water a long with how well the system meets the Ministry of Health (MoH) standards and how much the percentage decreases. The treatment improved the overall water quality, with most tests showing large decreases that met the regulatory standards.

Following treatment, most water quality parameters exhibited substantial improvement, whereas a few remained relatively stable, yet within acceptable regulatory limits. Turbidity decreased by 65%, with values decreasing from 14.00 to 4.96. Similarly, total dissolved solids (TDS) showed a 54% reduction from 738.6 to 336.35 mg/L. Color also improved significantly, dropping by 58% from 21.93 to 9.15 TCU. These changes indicate the system's effectiveness in removing suspended particles and dissolved contaminants, thereby enhancing the treated water aesthetic and sensory qualities. Chemical parameters also showed significant reductions. Alkalinity declined by 49% from 40.12 to 20.36 mg/L. Hardness was reduced by 47% from 266.27 to 141.69 mg/L, and the ammonia concentration decreased by 44% from 1.82 to 1.02 mg/L. All post-treatment values complied with the quality thresholds established by the MoH, indicating that the treated water achieved chemical stability suitable for domestic consumption.

Table 3. Comparison of water quality parameters before and after treatment

Parameter	Before	After	MoH Regulation	Reduction (%)
	Mean	Mean		
Turbidity (NTU)	14	4.96	<5	65
Temperature (°C)	21.79	22.5	±25	3
TDS (mg/L)	738.6	336.35	<500	54
Color (TCU)	21.93	9.15	<15	58
Alkalinity (mg/L)	40.12	20.36	<200	49
Ammonia (mg/L)	1.82	1.02	<1.5	44
Iron (mg/L)	0.05	0.04	<0.3	20
Hardness (mg/L)	266.27	141.69	<500	47
Manganese (mg/L)	4.68	2.77	<0.4	41
DO (mg/L)	5.48	8.24	≥5	33
pH	8.13	7.77	6.5-8.5	4
Lead (mg/L)	0.01	0.01	<0.01	0
Organic substances (mg/L)	9.80	5.44	<10	44
Total coliform (CFU/100 mL)	230	110	0	52

Note: TDS (total dissolved solids); DO (dissolved oxygen); MoH (Ministry of Health)

The manganese concentration decreased by 41% from 4.68 to 2.77 mg/L; however, this value remained above the regulatory maximum of 0.4 mg/L, highlighting the need for additional treatment to ensure complete contaminant removal. In contrast with these reductions, the DO concentration increased by 33% from 5.48 to 8.24 mg/L, reflecting enhanced oxygenation and support for aerobic biological processes. The water temperature minimally increased by 3% from 21.79 to 22.50°C, whereas the pH decreased slightly by 4% from 8.13 to 7.77. Both these parameters remained within the acceptable range by the MoH, demonstrating that the process did not significantly alter the thermal or buffering characteristics of the water. The iron concentration was reduced by 20% from 0.05 to 0.04 mg/L. The lead concentration remained constant at 0.01 mg/L. Thus, both parameters were also within regulatory limits. Organic matter concentrations declined by 44% from 9.80 to 5.44 mg/L, meeting the MoH standard of <10 mg/L. Microbiological analysis revealed a 52% decrease in total coliforms from 230 to 110 CFU per 100 mL, indicating partial microbial removal. These collective findings confirm that the compact filtration system effectively enhanced both the physicochemical and microbiological qualities of groundwater. However, persistent exceedances in parameters such as manganese and moderate levels of coliforms suggest the need for supplementary treatment processes to ensure full compliance with national drinking water quality standards.

Table 4 shows that all sampling locations initially exhibited DWQI scores within the "poor" (100-200) to "very poor" (200-300) categories, indicating that untreated groundwater from household dug wells was unsuitable for direct consumption due to elevated levels of turbidity, TDS, ammonia, and microbial contaminants. Following system implementation, the DWQI values substantially improved at most sites, with post-treatment scores predominantly falling within the "good" category (50-100). This shift demonstrates a significant enhancement in the overall water quality, rendering the treated water generally acceptable for drinking, although minor additional treatments are potentially beneficial in specific cases. The most notable improvements were recorded in Kendal and Semarang, where all sampling points improved from "poor" or "very poor" to "good." Conversely, some locations in the Demak Regency retained "poor" values even after treatment, suggesting localized limitations possibly linked to higher initial contaminant loads or reduced filtration efficacy due to system saturation. These findings highlight the effectiveness of the compact system as a decentralized water treatment solution while emphasizing the need for site-specific adjustments or supplementary treatment components to ensure consistent performance across variable groundwater conditions.

Table 4. DWQI scores before and after treatment by location

Location	DWQI Before	Interpretation	DWQI After	Interpretation
Kendal Regency				
Site 1	135.56	Poor	96.23	Good
Site 2	119.62	Poor	99.42	Good
Site 3	108.49	Poor	88.65	Good
Site 4	147.27	Poor	92.66	Good
Site 5	129.91	Poor	104.1	Good
Semarang City				
Site 1	155.38	Poor	102.77	Good
Site 2	200.91	Very poor	111.03	Good
Site 3	150.63	Poor	78.45	Good
Site 4	153.75	Poor	83.48	Good
Site 5	133.68	Poor	97.07	Good
Demak Regency				
Site 1	223.8	Very poor	108.96	Poor
Site 2	165.65	Poor	90.35	Good
Site 3	151.52	Poor	100.84	Poor
Site 4	126.23	Poor	97.48	Good
Site 5	130.53	Poor	97.88	Good

These results reaffirm the well-documented efficacy of compact filtration systems in improving physicochemical water quality, particularly parameters such as turbidity, TDS, color, and ammonia. The efficient removal of suspended solids and dissolved inorganic matter by the proposed system is consistent with previous findings that demonstrated comparable performance of both ultrafiltration and activated carbon systems used in rural and decentralized contexts (Apea et al., 2023). Similarly, the filtration system significantly reduced the hardness, alkalinity, and ammonia within acceptable regulatory limits, mirroring the findings of (Ghonimy et al., 2025) where ultrafiltration reduced the total suspended solids and organic compounds by >80% in wastewater reuse applications. The increased DO levels were consistent with those in previous studies, suggesting that enhanced aeration and organic load removal contribute to improved DO levels post-treatment. The manganese concentrations remained above the permissible threshold set by the MoH, which is consistent with challenges noted in earlier filtration studies reporting limited efficacy in metal removal without specialized adsorption media or additional chemical treatments (Molelekwa et al., 2014).

Microbiologically, the reduction in total coliforms by the system underscores its partial effectiveness in removing pathogens. This is broadly comparable to decentralized membrane filtration studies, which reported log reductions of 0.86 to 1.14 for total and fecal coliforms under field conditions (Francis et al., 2016). Although meaningful, these reductions were insufficient to fully comply with international microbial safety standards, highlighting the necessity for complementary disinfection methods, such as chlorination or UV treatment. Similar patterns were noted by (Molelekwa et al., 2014), where ultrafiltration alone achieved partial microbial removal but required integration with secondary barriers for full compliance. Furthermore, the negligible temperature and pH changes reinforce the existing literature that such parameters are typically unaffected by passive filtration systems, especially those that do not involve chemical dosing or biological processing. These findings support the general consensus that compact and decentralized filtration units are viable for improving chemical and aesthetic water quality in low-resource settings; however, further enhancements, especially for microbial safety, remain critical for comprehensive health protection.

3.2 Treatment efficiency

Table 5 shows a statistically significant improvement in DWQI after treatment ($p<0.001$). The mean difference was 51.67 with a standard deviation of 28.45, indicating that the drinking water quality improved substantially following treatment with the system.

Table 5. Paired sample t-test DWQI before and after filtration

Parameter	Mean difference	SD	p-value (2-tailed)	Interpretation
DWQI before - after treatment	51.67	28.45	0.001	Significant difference

Note: SD=standard deviation

Figure 3 presents the DWQI values before and after treatment across the five sites in the Kendal Regency, Semarang City, and Demak Regency. A consistent decrease in DWQI scores was observed after system implementation. In Kendal and Semarang, the pre-treatment DWQI values ranged from approximately 120 to >200, categorizing the water as “very poor” to “unsuitable for drinking,” whereas the post-treatment values decreased to <110 within the “moderate” quality range. Demak Regency, which recorded the highest initial DWQI values (>220 at Site 1), also showed significant improvement, with post-treatment values reduced to <120. These findings confirm that the household-scale treatment system effectively enhanced water quality in all tested locations, including those with high initial contamination levels, aligning with the statistical evidence in Table 5 and demonstrating its potential as a viable solution for improving access to safe drinking water in coastal Central Java.

The multistage purifier evaluated in this study consistently converted raw water from “poor” to “good” at all sites. This dramatic quality shift is consistent with the global evidence that well-designed point-of-use (POU) systems can greatly enhance drinking water quality. Household water treatment is widely used to improve water safety (Rao et al., 2025). Typical POU configurations combine sediment filtration, activated carbon adsorption, membranes, and UV disinfection to remove contaminants (Wu et al., 2021). Our system incorporates these elements by adding an initial aeration stage to oxidize iron and sulfide before sequential filtration and a final UV chamber, thereby targeting turbidity, organic adsorbates, and microorganisms.

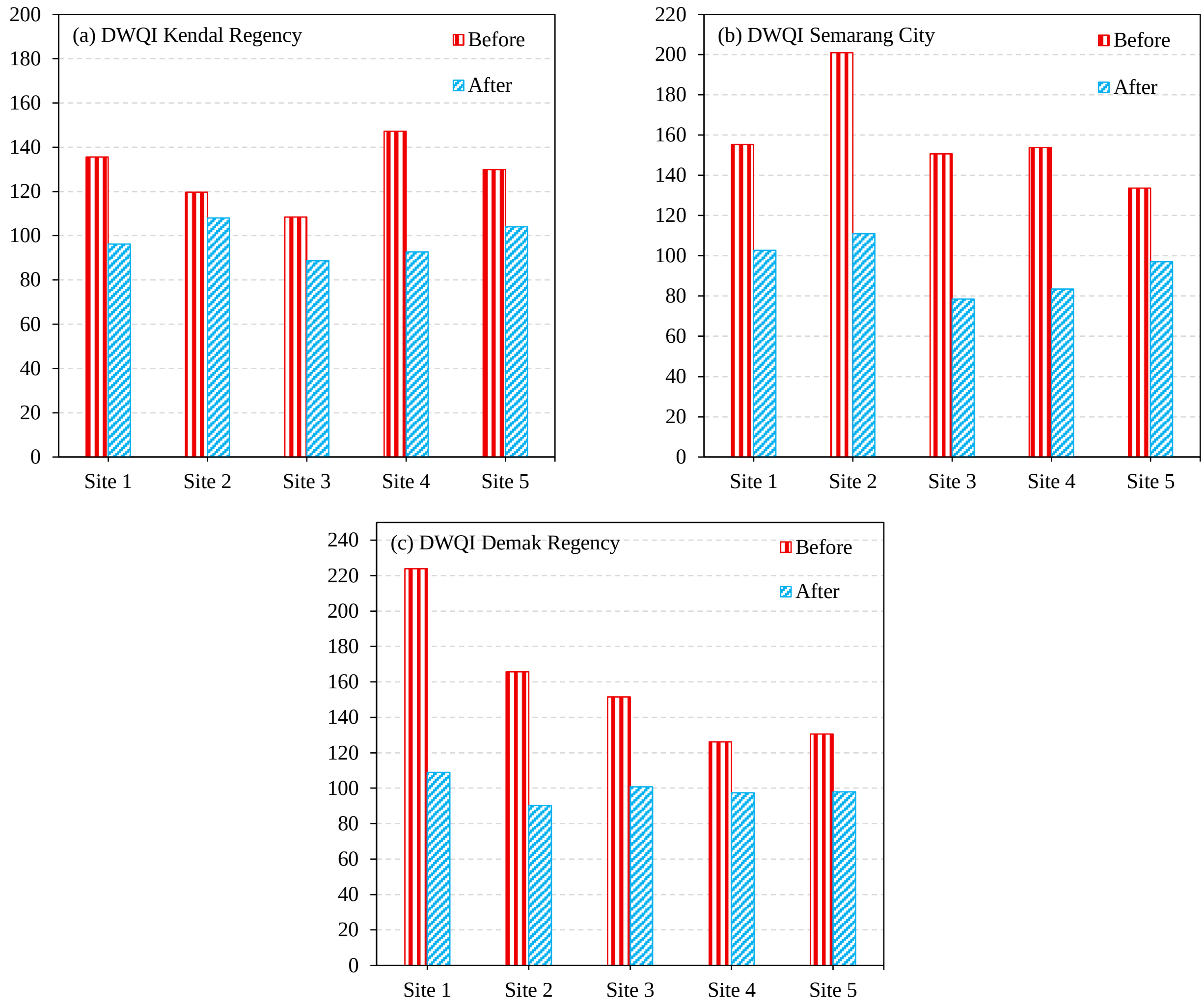

Figure 3. Comparative DWQI values before and after treatment

Field data showed that the system removal performance matched or exceeded those of benchmarks from recent studies. For example, Hincapié et al. (2025) tested household units (sedimentation + pre-filtration + UVC) in rural Colombia and Mexico and found >97% of treated samples achieved turbidity <5 NTU, with *Escherichia coli* driven to potable (non-detect) levels in every case. Hassan et al. (2024) reported that a layered nonwoven and cotton filtration unit achieved ~96% turbidity removal and 99.6% *E. coli* removal before chlorination/disinfection. Our compact unit produced treated water that met the WHO and Indonesian standards,which agrees with the high-efficiency outcomes. Similarly, a recent plateau region study in China found that installing RO-based POU systems “improved” compliance with drinking water standards compared with raw water (Zhang et al., 2020). In our study, the DWQI improvement from “poor” to “good” reflected a similar degree of contaminant reduction.

The novelty of the evaluated system lies in its tailored integration of processes in low-infrastructure contexts. Unlike many consumer POU filters often reliant on commodity cartridges and lack monitoring, this design is rugged and easily operable. By combining aeration, granular/adsorptive media, and UV light into one compact unit, multiple pollutant classes can be addressed synergistically. This multistage strategy parallels the “combined” treatment approach identified as most effective in recent reviews. For instance, Rao et al. (2025) noted that

HWT systems using combined coagulant-disinfectant steps achieved the highest microbial log removal. Although our unit uses physical oxidation instead of chemical coagulation, the analogous multibarrier structure yielded excellent purification across diverse source waters.

The compact purifier demonstrated data-driven performance on par with that of state-of-the-art POU technologies. The "good" DWQI score after treatment is quantitatively consistent with the >95% removal efficiencies reported in the literature. By achieving potable-quality water without centralized infrastructure, this system uniquely contributes to the field of household water treatment. Its innovation lies not in an untested theory but in applying proven physical, adsorptive, and UV processes in a novel configuration optimally suited to high-contamination, low-resource settings. These comparative insights confirm that the performance of the treatment unit is state-of-the-art and can be distinctly adapted to local challenges.

3.3 System performance limitations and process optimization strategies

Notably, when examined based on the microbiological parameters, the water did not meet the safe consumption standard of 0 CFU/L. This limitation aligns with previous studies indicating that microbial removal in decentralized or compact treatment systems is highly sensitive to operational parameters, particularly UV intensity and exposure duration. Adeniyi and Jimoh (2024) found that UV-C irradiation with sufficient dose (≥40 mJ/cm²) can remove up to 99.9% of bacterial contaminants, but suboptimal configurations may only inactivate some pathogens. Extending UV exposure time is a practical optimization approach capable of achieving higher disinfection levels with increased contact time, particularly at temperatures supporting microbial susceptibility (20-28 °C) (Lu et al., 2022).

Alternative, post-disinfection heat treatment can serve as an effective secondary barrier. Heat-based disinfection through boiling or controlled heating is widely recognized for its microbial effectiveness, particularly for inactivating resistant bacteria and viruses. Although this approach may increase the energy consumption, it ensures full compliance with Regulation No. 492/Menkes/Per/IV/2010, which requires the complete absence of coliform bacteria in 100 mL of drinking water. Other studies e.g., (Reed et al., 2022; Ruas et al., 2022) emphasize that the efficiency of filtration and disinfection processes is significantly influenced by the hydraulic retention time. Longer contact times allow for more complete adsorption, oxidative degradation, and microbial inactivation, particularly of persistent or slow-reacting contaminants.

To optimize the current system, two strategies are proposed: (1) UV contact time extension from 3 to 6 h to enhance microbial exposure and disinfection efficacy and (2) thermal disinfection stage integration to ensure complete microbiological safety. Although relatively minor in terms of system redesign, such adjustments can significantly improve system compliance with health standards and expand their applications to areas with high microbiological loads. Future prototypes could also benefit from the real-time monitoring of disinfection parameters and automatic flow rate adjustment to dynamically adjust the exposure based on initial contamination levels.

4. CONCLUSION

This study demonstrated the effectiveness of a compact household drinking water treatment system that integrates filtration, adsorption, aeration, and UV disinfection in significantly improving water quality by reducing color and total coliform counts while increasing DO. Aeration enhances the oxygen levels to support biological processes, and UV disinfection results in notable microbial reduction without side effects. However, the system showed limited effectiveness for turbidity, iron, manganese, ammonia, and lead concentrations, indicating the need for further optimization. Overall, this system presents a sustainable and decentralized solution for improving drinking water quality in coastal and resource-limited areas. Future studies should explore its broader pollutant removal and long-term performance.

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AUTHOR CONTRIBUTIONS

Sulistiyani S and Joko T contributed to the study design and literature review. Setiani O and Darundiati YH were responsible for data collection and software analysis. Rahman MA interpreted the results and drafted the manuscript. All the authors critically reviewed, edited, and approved the final version of the manuscript.

DECLARATION OF CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this study.

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