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The Effectiveness of Microplastic Removal in a Lake on the University of Indonesia Campus Using PVC (Polyvinyl Chloride) Ultrafiltration Membranes

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Abstract

Microplastic pollution is becoming an increasingly important environmental issue due to its potential to degrade water quality and negatively impact ecosystems and human health. Kenanga Lake, located in the University of Indonesia, is a water resource with the potential to be utilized as a raw water source, necessitating pollution control efforts, including those for microplastics. This study aims to design and analyze the performance of a Polyvinyl Chloride (PVC) ultrafiltration system in removing microplastics and improving lake water quality. The research method used a quantitative experimental approach with a pretest–posttest design through testing water samples before and after the filtration process. The PVC ultrafiltration system was equipped with a pretreatment unit in the form of a sediment filter and operated at pressure variations of 1; 1.5; and 2 bar and filtration times of 10, 30, and 60 minutes. The parameters analyzed included the number and characteristics of microplastics, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Conductivity. System performance was evaluated based on removal efficiency and log removal values. The research results are expected to provide information on the effectiveness of PVC ultrafiltration membranes in reducing microplastics and improving lake water quality as an alternative efficient and sustainable water treatment technology.

INTRODUCTION

Microplastics are plastic particles measuring less than 5 mm that originate from the degradation of plastic waste and products containing plastic (Haji et al., 2021). The presence of microplastics in aquatic environments is increasing along with population growth, domestic activities, and industrial development (Faizil, 2022; Nova Nevila Rodhi et al., 2026; Puja et al., 2026; Talahatu et al., 2025). Microplastics are a global concern because they are persistent, difficult to degrade, and have the potential to introduce various hazardous contaminants into aquatic ecosystems (Hanif et al., 2021).

Microplastic pollution can degrade water quality and disrupt ecosystem balance (K Biju, 2025; Liu et al., 2025; Ma & You, 2025; Parikh et al., 2025). In addition to impacting aquatic organisms through bioaccumulation, microplastics also have the potential to enter the human food chain (Liu, 2019). Various studies have shown that microplastics can adsorb persistent organic pollutants (POPs) and heavy metals, potentially increasing their toxicity to organisms and human health (Rochman et al., 2013; Li et al., 2018; Wang et al., 2019).

Ultrafiltration membrane technology is a promising method for microplastic removal due to its ability to effectively separate small particles (Djana et al., 2024). Polyvinyl Chloride (PVC) membranes are an attractive alternative due to their good mechanical and chemical resistance, relatively low cost, and widespread use in water treatment systems (Aryanti et al., 2023). Other advantages of PVC membranes include their excellent chemical resistance and film-forming properties, making them suitable for use as membrane materials (Rajabzadeh et al., 2020). However, PVC membranes are vulnerable to fouling during long-term operation due to their low intrinsic hydrophilicity and hydrophobicity, which can lead to clogged channels and shortened membrane lifespan (Yong et al., 2019).

However, studies on the effectiveness of PVC ultrafiltration membranes in removing microplastics from lake waters are still limited. Based on this condition, this study was conducted to design and evaluate the performance of a PVC ultrafiltration system in removing microplastics from Lake Kenanga, University of Indonesia. In addition to microplastics, this study also assessed the system's ability to reduce other water quality parameters, namely Total Suspended Solids (TSS), Biological Oxygen Demand (BOD), and Chemical Oxygen Demand (COD). The results of this study are expected to provide scientific information regarding the potential application of PVC ultrafiltration technology as an alternative treatment for surface water contaminated with microplastics.

Based on the background above, this study aims to design and analyze the performance of a Polyvinyl Chloride (PVC) ultrafiltration system in removing microplastics and improving lake water quality, specifically examining the types, sizes, colors, and polymer compositions of microplastics present in Kenanga Lake water, evaluating the effectiveness of the membrane in removing microplastics and improving water quality parameters (TSS, BOD, COD, TDS, and conductivity) at various operating pressures and filtration times, and identifying optimal operating conditions for maximizing removal efficiency. This research is expected to provide theoretical benefits by enriching membrane technology studies for microplastic removal in water treatment, particularly regarding PVC ultrafiltration membranes for lake water contaminated with microplastics, while contributing to the development of water treatment technology in the Indonesian context. Practically, this research serves as a reference for water treatment practitioners in designing membrane-based filtration systems, a basis for optimizing operating conditions to maximize membrane performance, and a foundation for future researchers in developing more effective and efficient microplastic removal technologies.

METHOD

Data collection used a quantitative approach with a pretest–posttest experimental design to evaluate the effectiveness of the Polyvinyl Chloride (PVC) ultrafiltration system in removing microplastics and improving the water quality of Kenanga Lake, University of Indonesia. The test was conducted by comparing the characteristics of the water before the filtration process (influent) and after the filtration process (effluent) using the PVC ultrafiltration system. The parameters analyzed included the number and characteristics of microplastics, Total Suspended Solids (TSS), Biochemical Oxygen Demand (BOD), and Chemical Oxygen Demand (COD).

Water samples were taken from Kenanga Lake, located in the core area of the University of Indonesia. Water sampling was carried out using the grab sampling method by taking water from the surface and a depth of 1-2 meters in the inlet area of Kenanga Lake, UI. After the samples were taken, they were then processed using a pilot-scale ultrafiltration unit equipped with a pretreatment stage in the form of two 10-inch sediment filters with pore sizes of 3 µm and 1 µm. The ultrafiltration system was operated using a dead-end filtration configuration with a processing capacity of approximately 2,000 L/hour. The study was designed using a Design of Experiments (DOE) approach with variations in operating pressure of 1.0; 1.5; and 2.0 bar and filtration times of 10, 30, and 60 minutes to determine the effect of operating conditions on membrane performance.

The ultrafiltration system used consists of a pretreatment unit, booster pump, filter cartridge, membrane housing, and PVC ultrafiltration membrane. The reason for selecting PVC membrane is based on its mechanical durability, chemical stability, suitability for micro-particle removal, and its advantages in terms of relatively more economical costs when compared to using membranes made of other materials. The calculation of system capacity is carried out based on the flux value and the effective area of the membrane. To achieve the planned operating capacity, two ultrafiltration membrane units are used, operated in parallel. The design of the ultrafiltration device that will be used in this study is shown in the following figure.

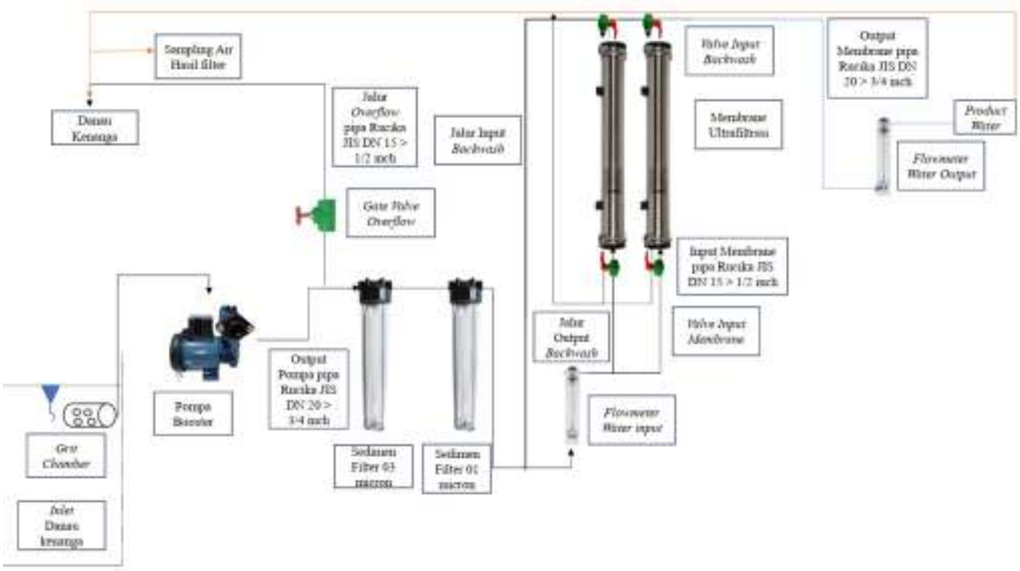

Figure 1. Ultrafiltration System Design

Testing was conducted by comparing conditions before filtration (influent) and after filtration (effluent) using a PVC ultrafiltration membrane. The resulting data was numerical and analyzed to determine the level of microplastic removal and changes in the concentration of water quality parameters.

The performance of the ultrafiltration system was evaluated based on the Removal Efficiency (RE) and Log Removal Value (LRV) values calculated from the differences in parameter concentrations in the influent and effluent. The obtained data were then statistically analyzed using a pre-treatment comparison test to determine the significance of microplastic removal and water quality parameters. The analysis results were used to assess the effectiveness of PVC ultrafiltration membranes as a treatment technology for surface water contaminated with microplastics.

After the ultrafiltration process, samples were taken to the laboratory for microplastic analysis, which involved identifying the number, shape, size, color, and type of particles found in the samples before and after filtration. Furthermore, water quality testing was conducted in the laboratory to determine the concentrations of TSS, BOD, and COD. The measurement results were used to evaluate changes in water quality resulting from the ultrafiltration process by comparing them with clean water and wastewater quality standards, and to evaluate the performance and effectiveness of the filtration unit in reducing pollutant concentrations.

RESULTS AND DISCUSSION

The research was conducted for two days, on June 1 and 2, 2026, at the inlet channel of Lake Kenanga, University of Indonesia campus, Depok. The research began at 12:00 noon and ended at midnight using an ultrafiltration membrane device as shown in the following figure.

Figure 2. Ultrafiltration membrane tool
(Source: Author's Documentation)

The research results show several types of microplastics and the amounts found during the research process. Sampling was carried out over two days with eight filtration cycles, each lasting 40 minutes, with a 5-minute backwash after each filtration process. However, the microplastic content sampling process was carried out on cycle 1 on the first day and the final cycle (cycle 8) on the second day of water sampling, as shown in the following table.

Table 1. Total microplastics in lakes kenanga in the inlet phase of the day to - 1

MP INLET CYCLE 1 DAY 1		
Type	**Color**	**Size**
fiber	blue	980
fragment	red	12.9
fragment	red	48.2
fragment	blue	11.5
fragment	red	9
fragment	purple	22.7
fragment	pink	10.7
fragment	red	62
fragment	blue	31.9

Source: Author's Data

Table 2. Total microplastics in lakes kenanga in the outlet phase of the day to - 1

MP Outlet Cycle 1 Day 1		
Type	**Color**	**Size**
fiber	black	3081.6
fiber	black	1573.1
fiber	blue	1095.4
fiber	transparent	194.9
fiber	transparent	937.2
film	transparent	402.7
film	transparent	759.4
film	transparent	108.9
film	yellow	1218.4
film	transparent	52.8
film	transparent	679.3
fragment	red	26.8
fragment	red	17.2
fragment	red	18.1

Source: Author's Data

Table 3. Total microplastics in lakes kenanga in the inlet phase of the day 2nd

MP INLET CYCLE 8 DAY 2		
Type	**Color**	**Size**
fiber	blue	94.5
fiber	blue	581.7
fiber	blue	614.5
film	blue	486.3
film	red	113.9
film	blue	1070.9
film	green	24.3
fragment	purple	11.7
fragment	blue	11.3
fragment	purple	12.4
fragment	turquoise	21.2
fragment	pink	26.8
fragment	red	22.3
fragment	green	119.4

Source : Author's Data

Table 4. Total microplastics in lakes kenanga in the outlet phase of the day 2nd

MP Outlet Cycle 8 Day 2		
Type	**Color**	**Size**
fiber	blue	654.8
film	blue	130.3
fragment	red	10.7

fragment	green	21.3
fragment	purple	25
granul	red	5.2

Source: Author's Data

On testing microplastics in lakes ylang-ylang UI Depok campus 4 (four) types were found microplastics like fiber, film, fragments, and granules with size varies between 5.2 – 3081.6µm. Based on abundance data microplastics on known that amount the most microplastics found various fragment amounting to 48.83% of all over microplastics found followed by with film of 25.58%, fiber 23.25%, and granules 2.32% with own various colors like blue, red, green, purple, black, yellow, and no own color (transparent) as in the picture following.

Inlet cycle 1 day 1	Outlet cycle 1 day 1	Inlet cycle 8 days 2	Outlet cycle 8 days 2

Figure 3. Microplastic Fiber
Source: Documentation Writer

Inlet cycle 1 day 1	Outlet cycle 1 day 1	Inlet cycle 8 days 2	Outlet cycle 8 days 2

Figure 4. Microplastics Fragment
Source: Documentation Writer

Outlet cycle 1 day 1	Inlet cycle 8 days 2	Outlet cycle 8 days 2

Figure 5. Microplastic Film
Source : Documentation Writer

Outlet cycle 8 days 2

Figure 6. Microplastic Granules
Source: Documentation Writer

Testing microplastics use stereo microscope and assisted with FTIR (*Fourier-transform infrared spectroscopy*) method with objective get structure chemistry microplastics, detecting and differentiating particle plastic that is sized bigger than 10 μm (Shim et al., 2017). Grouping microplastics aim know origin proposals and sources polluter from microplastics (Chia et al, 2021). FTIR test results on the day First show that type polymer plastic on the day First the inlet channel is made of Polyisobutylene (PIB) while known outlet channel High Density Polyethylene (HDPE) type. Meanwhile, in the test day second known type polymer plastic detected in the inlet channel is dominated by Styrene Butadiene Rubber (SBR) type, which is common originate from tire particles, seals, or elastomeric materials and polyisobutylene rubber outlet channels with carbon black content, as well as indication of PTFE/fiberglass material which has characteristics elastic. Here FTIR graph on microplastic test samples on the day first and second in the research This.

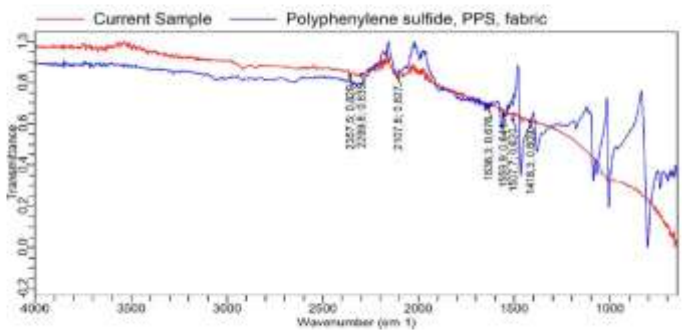

Figure 7. FTIR test results on a 1- day inlet cycle to - 1
Source: Author's Data

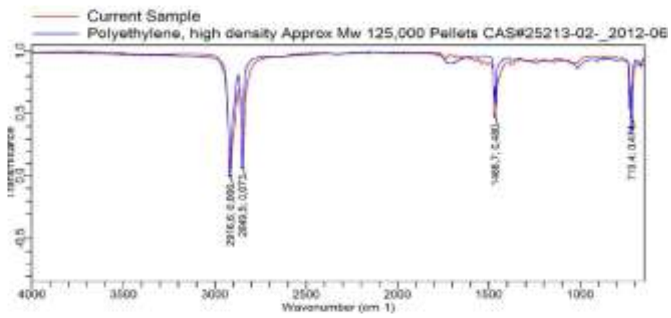

Figure 8. test results on a 1- day outlet cycle to - 1
Source: Author's Data

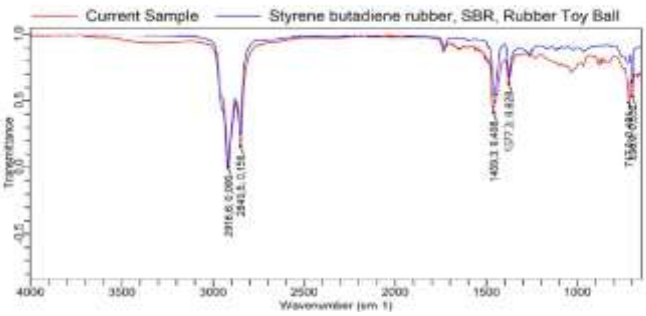

Figure 9. test results on an 8- day inlet cycle 2nd
Source: Author's Data

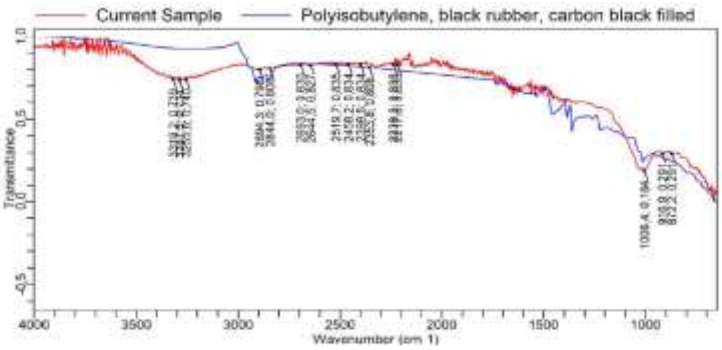

Figure 10. FTIR test results on an 8- day outlet cycle 2nd
Source: Author's Dat

Test results microplastics show improvement amount particles in phase after the filtration process use ultrafiltration membrane device while in testing day second happen decline amount particles in phase after the filtration process. This is caused by Because release particle from system filtration that is still experience conditioning stage, distribution microplastics that are not homogeneous in lake water samples, and it is suspected happen contamination during the filtration process ongoing (Bogdanowicz, et al 2021). Weaknesses in the study This is the frequency testing microplastics relatively A little so that level effectiveness use membrane ultrafiltration considered not enough accurate and not yet describe actual conditions

CONCLUSION

Based on research conducted on a polyvinyl chloride (PVC) ultrafiltration system in Lake Kenanga at the University of Indonesia, it can be concluded that the lake water contains various types of microplastics, dominated by fragments, followed by films, fibers, and granules of varying sizes and colors. The presence of these microplastics indicates that Lake Kenanga has experienced microplastic pollution originating from anthropogenic activities in the surrounding environment. The performance of the PVC ultrafiltration membrane in this study showed varying results in each test cycle. In certain tests, there was an increase in the number of particles after filtration due to the system conditioning process, the potential release of particles from the filtration unit, and the possibility of contamination during sampling. However, in other cycles, the system also demonstrated the ability to reduce the number of microplastics. Thus, overall, the PVC membrane has potential for microplastic removal, although it is not yet optimally stable. Furthermore, FTIR analysis showed a variety of polymer types, such as polyisobutylene (PIB), high-density polyethylene (HDPE), styrene butadiene rubber (SBR), and other elastomer-based materials, indicating that the source of pollution is domestic activities and synthetic materials in the lake's environment. Thus, it can be concluded that the PVC ultrafiltration system has the potential to be used as an alternative technology in the treatment of microplastic-contaminated water, but its effectiveness still needs to be improved through optimizing operating conditions, increasing membrane stability, and controlling contamination factors so that the removal results are more consistent and accurate.

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