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Increasing Water Quality and Scalability of Peatland Water with Double Flow Ultrafiltration in South Borneo

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ABSTRACT

Peatlands have ecological importance, human activities and climate change have created various environmental challenges for peatlands. One of the problems with peatlands is the degression in the quality of peat water, which has a negative impact on ecology and human health as well as the welfare of local communities who depend on peat water as a source of clean water. The problem of peat water processing lies in the need for large capacity, ease of maintenance, and water quality that meets standard criteria. The aim of this research is to evaluate the combination of filtration, absorption, and double flow ultrafiltration techniques, and compare them with single flow ultrafiltration techniques for treating peat water in the South Kalimantan region of Indonesia by looking at the amount of production and quality of water treatment results. This research proposes dual flow ultrafiltration as a solution for treating peat water on a large scale up to 2 times and results in better water quality than single flow ultrafiltration treatment. This is indicated by the percentage difference in TDS reduction of 19.5%, color of 23.1%, nitrite of 37.8%, and manganese of 69%. However, the dual flow ultrafiltration method still has a higher turbidity of around 60.65% and nitrate of about 15%. However, these water treatment results are still standardized by the Indonesia Minister of Health PERMENKES No.492/MENKES/PER/IV/2010.

Keywords: peatland water, double flow, single flow, South Borneo.

INTRODUCTION

Peatlands serve a significant function in the regulation of the world's climate, the sequestration of carbon, and the conservation of biodiversity. This exceptional ecosystem occupies roughly 3% of the planet's terrestrial area, yet it retains almost 30% of the earth's soil carbon [Hansen, 2013; Miettinen et al., 2012]. Among the critical issues that peatland regions confront is the deterioration of water quality, which not only jeopardizes the health of these delicate ecosystems but also affects the welfare of the neighboring communities that heavily rely on them for potable water [Miettinen et al., 2012; Youcai, 2018]. The growth of human populations and increase in industrial activity have led to an upsurge in the requirement for clean water, thereby exerting unparalleled strain on peatland water resources. Peatland water sources are susceptible to contamination by water pollutants such as suspended solids, dissolved organic matter, heavy metals, and nutrient compounds, which can seep into the water bodies and compromise their quality, potentially causing detrimental impacts on both the environment and human health [Angel Martínez-Morales, 2005; Fan &

Shibata, 2015]. Conventional water treatment technologies are often inadequate to address the unique challenges posed by the complex composition of peatland water and its sensitivity to external disturbances. In contemporary times, ultrafiltration has surfaced as a propitious technology for water treatment, displaying considerable potential for the purification of peatland water. This is achieved while simultaneously preserving the ecological equilibrium of these ecosystem [Guibai et al., 2010; Xiaoying F, 2017]. The process of Ultrafiltration encompasses the utilization of semipermeable membranes to effectuate the separation of particles, colloids, and macromolecules from water, with the basis of separation being the molecular size of these components.

South Borneo, similar to numerous other regions in Indonesia, frequently encounter hurdles concerning the accessibility of uncontaminated water. The modifications in precipitation and deforestation trends can result in a reduction of natural water reservoirs, comprising rivers and wells, that are the primary origins of unpolluted water for people [Fezzi et al., 2017; Masese et al., 2012]. Climate change is causing increased temperatures and unstable rainfall patterns in South Borneo [Sukmara et al., 2022]. This can impact the water cycle, resulting in a longer and more intense dry season [Tolosa & Tolossa, 2021]. The transformation presents a formidable challenge to the viability of dependable and enduring uncontaminated water supply in South Borneo. Furthermore, the matter of water quality is of paramount significance. Water that does not conform to health and sanitation criteria can trigger health complications for people, particularly in relation to waterborne ailments such as diarrhea and gastrointestinal infections [Patunru, 2015; Sutarto & Surjono, 2020]. In an effort to overcome the challenges of clean water needs in South Borneo, a sustainable water management approach is needed.

People situated in peatland environments must ensure that their students' clean water needs are met. This study focuses on the success of producing water quality that is suitable for consumption in accordance with the regulations set forth by the Minister of Health. The study aims to achieve this by utilizing a combination of filtration, absorption, micro filtration, and the double flow ultrafiltration method, in comparison to the single flow method. The implementation process and comparison of water quality using a double flow ultrafiltration process and a single flow ultrafiltration are the key focus areas of this research.

MATERIALS AND METHODS

Peatland and peat water formations

In Indonesia, peatlands play an important role in providing optimal ecosystem functions, including regulating water flow and as a buffer for the movement of salt or fresh water.

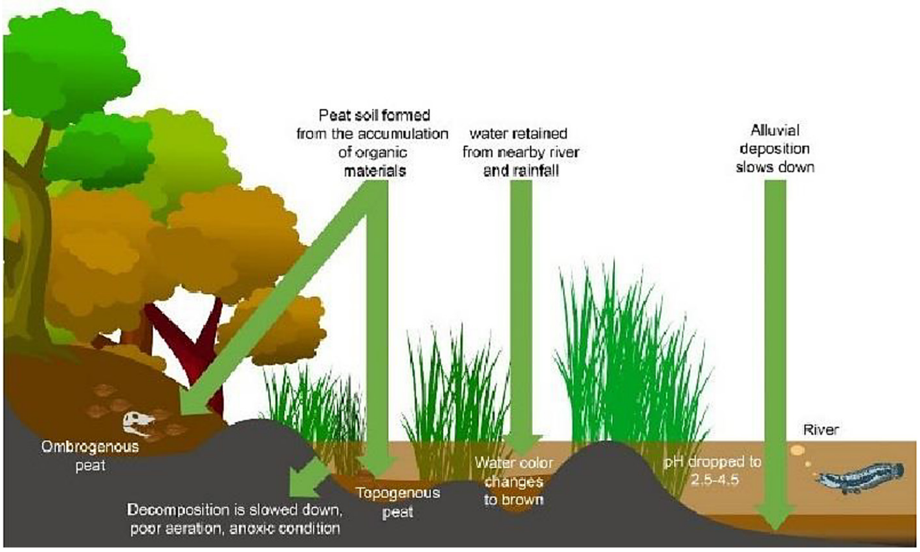

Figure 1. Peatland condition illustration

Hydrological processes affect the condition of peatlands. Its existence depends on retaining water and its characteristics depend on the origin, volume, chemical quality and variability of water supply. Peatland is a type of terrestrial wetland formed from the accumulation of organic matter deposits and is influenced by moisture, topography, geological conditions, pH, and nutrient availability. In the tropics, peatlands are widespread in Southeast Asia, East Asia, South America, and South Africa, as well as in the Caribbean and Central America [Page et al., 2006] (Figure 1). Although a peat blanket can retain a significant amount of water, only a small amount is deemed viable due to the absorption of rainfall [Devi et al., 2019].

Peat swamp forests store rich carbon and water [Tonks et al., 2017]. Nevertheless, owing to the dearth of alternative raw water sources, denizens residing in peatland regions rely heavily on peat water as their primary water source. Peat water, characterized by its brown hue, acidic nature, and richness in nutrients, possesses a pH value of 5.2, which can be attributed to the heightened concentration of natural organic matter in the form of humic acids [Notodarmojo et al., 2017]. The concentration of organic matter in peat soils ranges from 70 to 97% [Raghunandan & Sriraam, 2017]. The content of natural organic matter depends on soil conditions and climatic conditions. The concentration of natural organic matter in peat water is also influenced by the geographical and climatic conditions of peat swamp areas [Ritson et al., 2016; Yallop & Clutterbuck, 2009]. Red-brown peat water is a naturally occurring hue imbued with colloidal particles that possess a positive charge and are impervious to precipitation via gravitational forces. Thus, specialized treatment methodologies are needed [Elma et al., 2022]. Peat water is potentially hazardous for human consumption owing to the occurrence of compounds produced from the humification process, which comprises humic and fulvic acids, and also the minerals Fe and Mn, as stated in reference [Atmana Sutapa et al., 2020]. Consequently, specialized treatment is essential before utilizing it as a source of clean or drinking water. The high concentration of organic elements in peat water renders it unsafe for drinking; thus, drinking untreated peat water could result in various health concerns, including poisoning [Ritson et al., 2016].

Filtration

There exist various techniques employed in industrial water treatment to treat water based on the quality of the incoming water and the required output standards. Among these techniques are electrochemical precipitation, complexation, membrane filtration, ion exchange, and reduction [Simon et al., 2013]. Furthermore, membrane filtration processes possess an enormous separation potential that enables the achievement of numerous water standards [Zheng et al., 2015]. This technology is highly advantageous due to its modular nature, which allows for its application on both larger and smaller scales.

Filtration research is primarily focused on conventional sand filtration or commercially available ultrafiltration membranes. However, due to the presence of natural organic matter in peat water, the conventional filtration process using a sand filter has little impact. This is because sand filtration is typically used to filter flocs formed during the coagulation process that are not entirely deposited by gravity [Khayan et al., 2022]. Therefore, a more intricate filtration process is required to eliminate the presence of hydrophobic natural organic matter such as humic acids from peat water.

Ultrafiltration (UF) presents an alternative technology to enhance water quality. Nevertheless, membrane fouling remains an inevitable problem [Akhondi et al., 2014]. The coagulation-ultrafiltration process has been shown to effectively remove hydrophobic natural organic matter from peat water, with a removal rate of 97.4% [Mahmud et al., 2020]. However, since peat water contains high concentrations of hydrophobic natural organic matter in the form of humic and fulvic acids, ultrafiltration can often result in membrane fouling, particularly if it is not combined with other processes [Elma et al., 2022]. Ultrafiltration processes have been extensively employed not only for the purpose of rejecting Dissolved Organic Matter, but also for the elimination of heavy metals such as Cd2+, Co2+, Ni2+, and Cu2+, with a 96% allowance. The utilization of activated carbon (AC) powder in conjunction with ultrafiltration membranes for the removal of organic compounds in drinking water treatment has been investigated [Hidalgo & Murcia, 2021]. Consequently, further research utilizing alternative filtration methods is necessary to eliminate the presence of natural organic matter, as well as other natural and anthropogenic pollutants in peat water. This study amalgamates a variety of processes including absorption filtration, microfiltration, and ultrafiltration.

Adsorption

Pretreatment plays a crucial role in managing membrane fouling caused by waste organic matter. The effective elimination of suspended particles, colloids, and microbiological impurities is attainable through UF/MF filtration [Durham et al., 2001; Her et al., 2003; Vedavyasan, 2007]. Adsorption is a well-established approach that can eliminate diverse types of water-soluble pollutants. Due to its strong affinity for eliminating hydrophobic organic compounds even at low concentrations, it is a process that can remove dissolved organic matter from water [Jacangelo et al., 1995]. Many research works have been conducted to treat peat water using activated carbon for removing humic substances and organic matter, and activated carbon has been shown to be an effective adsorbent for water with high concentrations of organic compounds [Eltekova et al., 2000; Syafalni et al., 2012]. The high solubility of metals such as Fe in peat water is due to its acidic nature, and oxygen is used to treat it in peat water. Aeration and filtration, chlorination and filtration, and potassium permanganate and filtration have all been utilized in Fe processing studies [Podgórni & Rząsa, 2014]. The usefulness of zeolite stems from its large microporous and mesoporous volume and resulting high surface area [Fu & Wang, 2011]. Low-cost adsorbents like zeolite have been widely researched in a variety of fields, particularly in water treatment. Natural zeolite has a negative surface charge, which gives it an advantage in absorbing unwanted positive ions in water, such as heavy metals [Ibrahim et al., 2010].

Experimental application on Peat Water

The sampling of this study was on borehole peat water in South Borneo. Both samples are located in peatland environments with water characteristics, namely peat water. Peat water in these places results in brown and smelly water storage environmental conditions. So that as a source of drinking water and clean water is not feasible in reality. The process of data collection using sterile bottles with the target of analysis is biological, chemical and physical testing. The condition of peat water is as follows (Figure 2):

Figure 2. Source peat water for experiment

Research flow

This research uses appropriate technology by integrating several water treatment techniques with modifications of filtration, absorption and ultrafiltration (Figure 3). The integration is proposed as a double flow ultrafiltration method. This peatland water treatment process consists of several processes, early-stage raw water treatment, semi-finished raw water treatment stages, ready-to-treat water treatment stages, and ready-to-consume water stages. The stages of the technological process start with the peat water being processed into initial raw water, with a filtration process, and then the semi-finished raw water is processed, with a re-filtration process becoming semi-finished raw. The semi-finished raw water is then processed using double flow ultrafiltration to become large capacity, and the last treatment uses ultraviolet to ensure the death of bacteria in ready-to-drink water. This method was applied in the treatment of borewell peat water in South Borneo as testing. The research flow carried out is from preparation as a basis for determining filtration, absorption, microfiltration both process and stamp. Observations were made of peat water sources in South Borneo. Output of this observation are the basis for information on existing conditions before the treatment of this peat water treatment process. This peat water treatment design can be carried out and implemented according to the description of the condition of the peat water to be treated. Water before treatment and after processing is sampled and parameter testing in the laboratory BBTKLPP (Center for Environmental Health Engineering and Disease Control) Banjarbaru. The design of the double ultrafiltration method is as Figure 4. The design of the single ultrafiltration design method is as Figure 5.

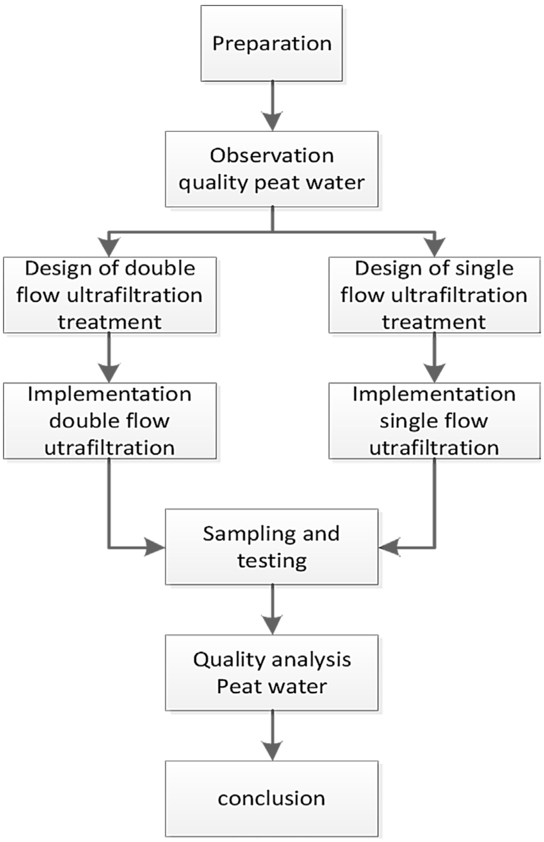

Figure 3. Workflow of research

The results of observations in determining filtration and absorption materials, the composition used is silica sand, activated sand, zeolite, activated carbon with a capacity of 35 kg

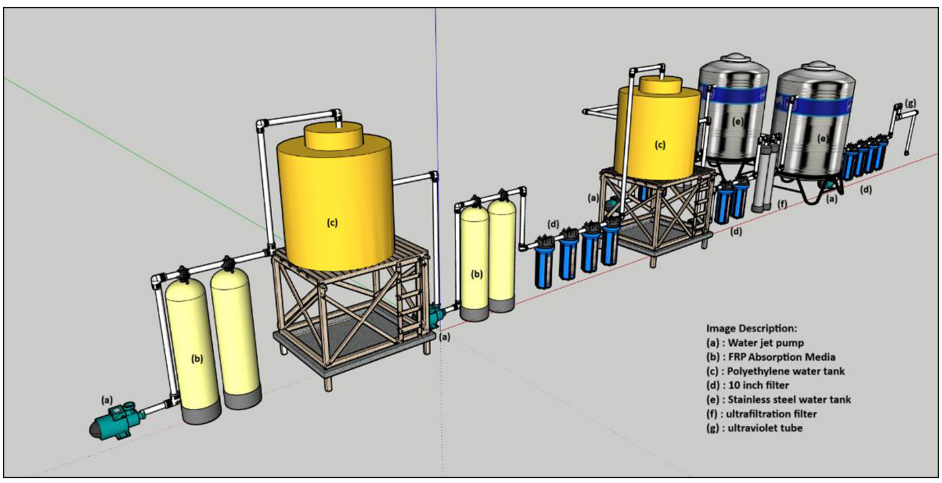

Figure 4. Double flow ultrafiltration

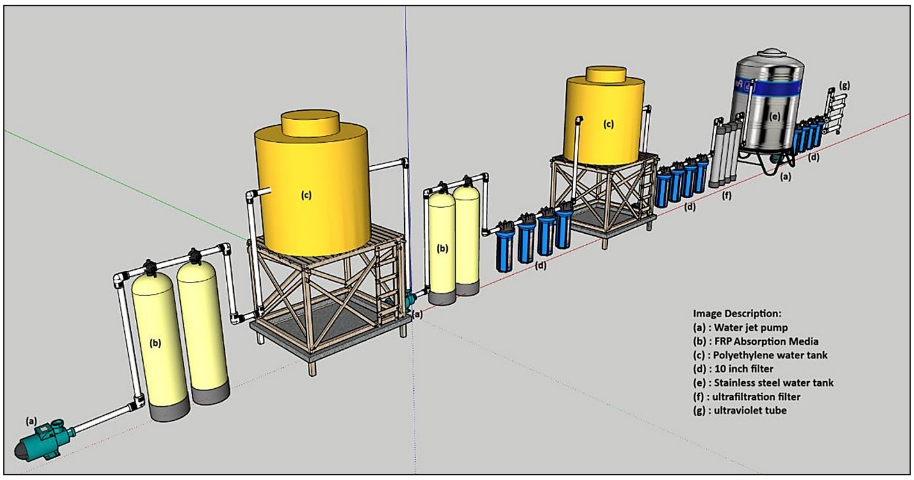

Figure 5. Single flow ultrafiltration

fiber filtration tube 1045. The filter consists of a composition that has its own function, including silica sand which serves to remove mud or soil and sediment content, the second composition is active sand which serves to remove iron content (Fe), remove a little manganese ($Mn2 +$) and yellow color in peat water. The composition of zeolite that serves to remove high levels of iron content (Fe), pungent iron odor, Manganese (Mn^{2+}), yellow color in water. The composition of activated carbon that functions to absorb odors, colors, chlorine or other minerals in water.

Installation of water reservoirs along with water paths from peat water sources to become clean water that is ready for use shown in Fig 6. in order for water to continue to be fulfilled, it uses an automatic system that will turn on the pump when the reservoir is empty. This reservoir is adjusted to the process of smart double flow ultrafiltration and smart single flow ultrafiltration stages, from the initial raw water treatment stage, semi-finished raw water treatment stage, ready to treat water treatment stage and ready for consumption water stage shown in Fig. 7 below.

In this study, peat water sampling was carried out on clear and sunny weather. The peat water was taken as many as 4 (four) samples at each place so that the total samples to be filtered were 8 (eight) samples. Sampling is a

Figure 6. Assembly and implementation process

Figure 7. Assembly of (a) double ultrafiltration and (b) single ultrafiltration

2-liter jerry can bottle for chemical and physical tests and 2 of 500 ml sterile glass bottle for biological tests, each sample consists of pre-treatment and post-treatment. Water quality tests in the BBTKLPP Laboratory (Center for Environmental Health Engineering and Disease Control) Banjarbaru are in accordance with drinking water standards based on PERMENKES No.492/MENKES/PER/IV/2010.

RESULTS

The production results from double ultrafiltration water treatment can produce up to a capacity of 4000 liters with a flow rate of 40 l/minute, while the production results from single ultrafiltration water treatment only produce 2000 liters with a flow rate of 20 l/minute. The water physics parameters testing post-treatment of the double ultrafiltration and single ultrafiltration process, shown in Table 1. The water chemical parameters testing post-treatment of the double ultrafiltration and single ultrafiltration process, shown in Table 2. The water biological parameters testing post-treatment of the double ultrafiltration and single ultrafiltration process, shown in Table 3.

DISCUSSION

Comparison results of water physics parameters of the double flow ultrafiltration method and single flow ultrafiltration shown in Figure 8. The results of the water physics parameter test show that the double flow ultrafiltration method provides better results than the single flow ultrafiltration method. This difference is shown in a decrease in TDS value by 19.5%, a decrease in color condition by 23.1%. However, the double flow ultrafiltration method still has a higher turbidity level of 60.65% compared to the single flow ultrafiltration method. Comparison results of the water chemical parameters of the double flow ultrafiltration method and the single flow ultrafiltration method shown in Figure 9 and 10.

The results of the water chemical parameter test show that the double flow ultrafiltration method provides better results than the single flow ultrafiltration method. This difference is shown in a decrease in pH value by 2.4%, a decrease in nitrite content by 37.8%, and a decrease in manganese value by 69.3%. However, the double flow ultrafiltration method still has a higher nitrate content of 15% compared to the single flow ultrafiltration method. While the value of other water chemical parameters

Table 1. The water physics parameters of post-treatment

Physical test	Double ultrafiltration	Single ultrafiltration
Temperature	24.5	24.7
TDS	163	242
Turbidity	0.13	0.53
Color	<5	8

Table 2. The water chemical parameters of post-treatment

Chemical test	Double ultrafiltration	Single ultrafiltration
Acidity (pH)	7.46	7.82
Nitrite (N02)	2.86	1.29
Nitrate (N03)	0.0752	0.1017
Valence chrome 6 (Cr6+)	<0.0003	<0.0003
Iron	<0.048	<0.048
Manganese	<0.0109	0.06
Residual khlor (Cl2)	0	0
Arsenic (As)	<0.0021	<0.0021
Cadmium (Cd)	<0.0003	<0.0003
Lead (Pb)	<0.0003	<0.0003
Fluoride (F)	<0.0073	<0.0073
Aluminium (Al)	<0.05	<0.05

Table 3. The water biological parameters of post-treatment

Biological test	Double ultrafiltration	Single ultrafiltration
Coliform	0	0
Escherichia coli	0	0

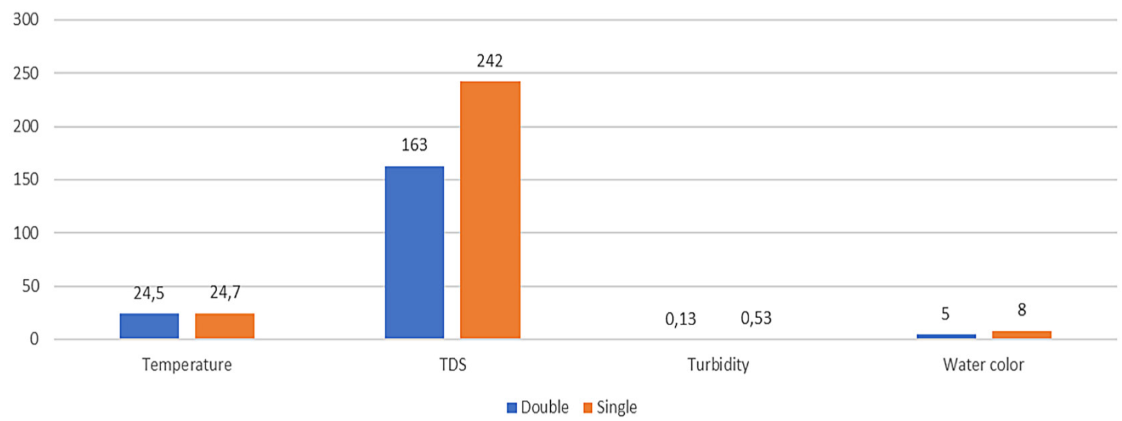

Figure 8. Post-treatment of physical parameter between the two methods

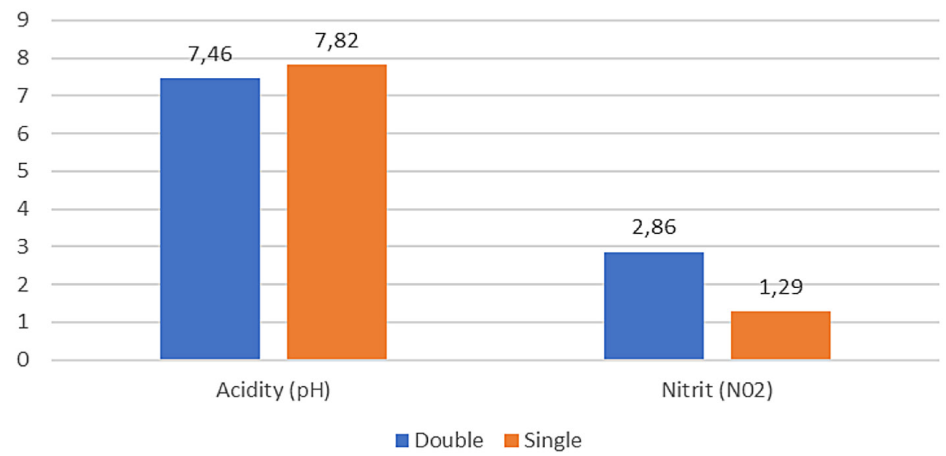

Figure 9. Post-treatment of chemical parameter between the two methods

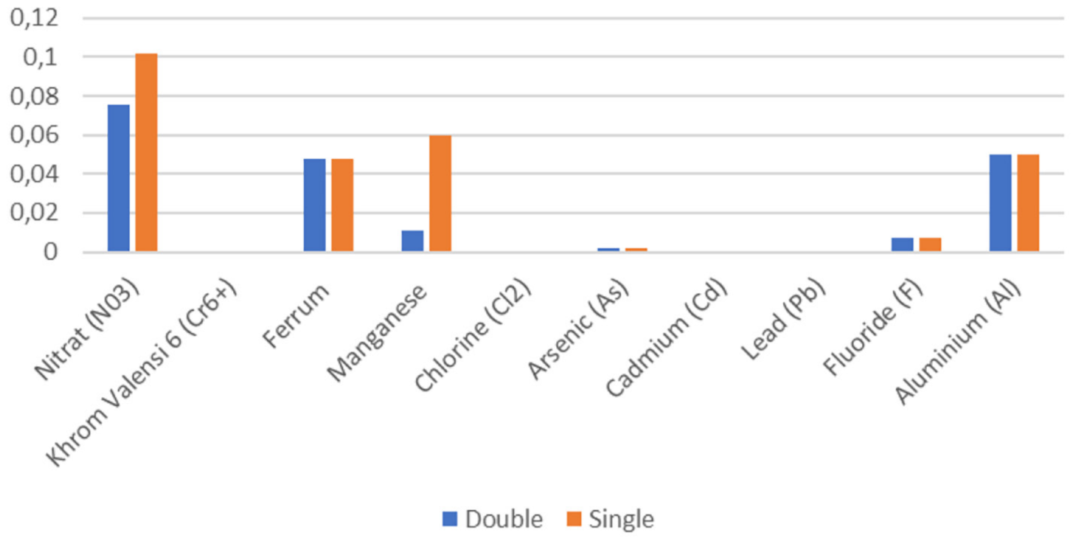

Figure 10. Post-treatment of chemical parameters between the two methods (cont.)

Table 4. The water parameters with other treatment

Physical test	Double ultrafiltration	Single ultrafiltration	IPAG60	Combination of neutralization, coagulation and filtration
Turbidity	0.13	0.53	1	6.55
Color	<5	8	2	179
Acidity (pH)	7.46	7.82	6.7	5.57
Iron	<0.048	<0.048	<0.009	0.26
Manganese	<0.0109	0.06	0.039	-

shows the same value between the two methods. In testing biological parameters, between the two methods did not show any difference in results. This is because, at the end of the water treatment process, ultraviolet light is added to both water treatment methods. Comparison results of double flow ultrafiltration method, single flow ultrafiltration method with another treatment method such as combination of Neutralization, coagulation and filtration [Parabi et al., 2019], IPAG60 [Ali et al., 2021]. The result comparison shown in Table 4.

The analysis findings are derived from the utilization of two methods, specifically double flow ultrafiltration and single flow ultrafiltration. Consequently, in order to achieve substantial production capacity, double flow ultrafiltration can be deployed for the treatment of peat water. Compared with other treatment methods shown that double ultrafiltration provides better results than others, especially in turbidity, color, and manganese. The executed filtration procedure illustrates that the key stages for generating high-quality water are the initial treatment of raw water and the intermediate treatment of semi-finished raw water, which involve the implementation of filtration techniques such as membrane filtration and absorption.

CONCLUSIONS

In conclusion, the application results show that the double flow ultrafiltration method in peat water treatment provides better water quality results compared to single flow ultrafiltration treatment. Even with flow sharing to increase production capacity up to 2 times. This is shown by the percentage difference in the reduction of TDS by 19.5%, color by 23.1%, nitrite by 37.8%, and manganese by 69%. However, the double flow ultrafiltration method still has a higher turbidity content of 60.65% and a nitrate content of 15%. Based on this research, the application of dual flow ultrafiltration processing can be proposed as a processing solution to increase water production capacity without reducing the quality of peat water, especially peat water from the South Kalimantan.

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