Efficacy of calcium lactate as a biodegradable coagulant for peat water purification: an experiment comparative study

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ABSTRACT

Kalimantan relies significantly on peat water as a water source. However, due to its high organic content, acidic nature, and intense color, it is not safe to drink. To address this issue, researchers proposed an eco-friendly coagulant, calcium lactate, to remove suspended solids. To test its effectiveness, the coagulant was compared to membrane technologies, specifically nanofiltration (NF) and reverse osmosis (RO), at Rasau Jaya General Hospital in West Kalimantan between April and October 2022. Different pressures, 40, 60, and 80 Psi, were used to test both methods. Before and after treatment, the levels of total coliform, *E. coli*, pH, total dissolved solid (TDS), turbidity, color, and calcium were examined. The results showed that the best outcomes were achieved at 60 Psi. The combination of 0.8 mg/l calcium lactate and NF met all the standard values, except for color (29 TCU). Calcium lactate and RO, however, produced safe drinking water at 60 Psi from all analyzed parameters (*E. coli*=0, total coliform=0, pH=6.5, TDS=7.1, nephelometric turbidity units (NTU)=2.8 NTU, color=8.7 TCU, and calcium 7.6 mg/l). The reduction of bacteriological substances achieved 100% for both methods. Overall, the combination of calcium lactate and RO yielded slightly better results than NF.

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1. INTRODUCTION

Water scarcity and the high demand for safe drinking water have profoundly impacted human life, particularly in underdeveloped nations and rural communities. Access to clean drinking water is a fundamental human need, and it must meet the standards set by physics, microbiology, and chemistry. Unfortunately, in Indonesia, access to safe drinking water remains relatively low. According to the quality study of household drinking water, only 11.8% of households in Indonesia have access to safe drinking water quality, as measured by *E. coli*, pH, nitrate, and nitrite parameters [1]. The issue of safe drinking water is not just limited to quantity. Still, it is also influenced by water quality, which can be affected by environmental pollution and the nature of water sources.

Many areas experiencing water scarcity are located in places where water is abundant, such as wetlands and peatlands, which make up around 4-6% of the world's land area [2]. Indonesia boasts the world's largest tropical peatland and the fourth-largest peatland overall, which has a direct impact on the quality of surface water [2]. Peat water is characterized by it is dark brown to blackish color (124-850 PtCo), high organic content (138-1,560 mg/L $KmnO_4$), and acidic nature (pH 3.7-5.3), all of which fall below clean water quality standards [3], [4]. In Kalimantan, an area almost entirely covered by peatlands, locals have had to take extra precautions to ensure access to safe, potable water.

Membrane technologies are fast gaining popularity as a sustainable solution for wastewater treatment and reuse [5]. Their benefits are manifold, with the ability to eliminate various pollutants and yield superior effluent quality, simple operation, and a compact size that saves space and reduces chemical usage compared to conventional treatment systems [6]. Additionally, the membrane filtration process differs from traditional and biochemical methods, which are heavily influenced by environmental factors like temperature, oxygen levels, and variations in feed composition [7].

Membrane technologies, such as nanofiltration (NF) and reverse osmosis (RO), are often used for water treatment to remove dissolved organic matter and ions [8], [9]. In peat water, NF has been found to significantly improve acidity levels within the pH range of 3-11, resulting in better rejection rates [10], [11]. This increase in pH also leads to higher efficiency in removing manganese (Mn) and iron (Fe). On the other hand, RO membranes have been effective in removing iron from groundwater [12].

While both membrane technologies are effective, it is essential to also take into account the use of coagulants. These substances serve to eliminate a range of dangerous materials, such as organic matter and pathogens. The combination of membrane filtration and coagulants has garnered considerable interest due to it is ability to surpass the constraints of traditional water treatment processes. Several studies have demonstrated that this approach outperforms either technique utilized separately [13]–[15]. Nevertheless, it remains a challenge to locate an environmentally sustainable coagulant, and this is a problem that requires attention.

Calcium lactate is a trusted food additive and coagulant that is frequently utilized to maintain the texture of pickled vegetables [13], as well as prevent tooth decay in sugar-free foods. It is also utilized to treat calcium deficiencies and decrease acidity. Prior research has indicated that calcium lactate has the ability to eliminate colored compounds and lignin [16]. However, there is a paucity of research on its efficacy as a coagulant in combination with membrane techniques for purifying peat water [13], [17]. The goal of this study is to examine the effectiveness of calcium lactate as a coagulant in conjunction with NF and RO under varying pressures to purify peat water samples for safe drinking water. The outcomes of this study may suggest that calcium lactate is an environmentally friendly and biodegradable coagulant that can effectively remove physical, bacteriological, and chemical impurities from peat water.

2. METHOD

This experiment was conducted in Rasau Jaya General Hospital, West Kalimantan from April to October 2022. This study did not require any ethical clearance as it did not involve human subjects. Peat water samples were taken from the study area. The parameters measured are the key parameters in drinking water standards, namely total Coliform, *E. coli*, pH, total dissolved solid (TDS), nephelometric turbidity units (NTU), color, and calcium. A variation of the treatment is to add calcium lactate coagulant to the NF membrane and RO with 3 different pressures (40 Psi, 60 Psi, and 80 Psi). The treatment repeats 3 times each, so the number of samples in this study is (3 variations × 2 membranes) × 3 repetitions + 2 controls = 20 test samples. The experimental setup included 2 tanks for peat water, 2 reactors for calcium lactate mixing, a microfilter (cartridge 0.1 μm), 2 dosing pumps, 2 boost pumps, a NF unit, and RO. The NF and RO membranes' capacity is 2,000 gallons per day (GPD) each. A schematic diagram of the experimental setup is shown in Figure 1.

Peat water from the river is pumped into a holding tank while a calcium lactate solution is injected using a dosing pump. The dose of calcium lactate used is 0.8 mg/l (based on the results of previous Jar tests). Peat water in the holding tank and a place for coagulation-flocculation and sedimentation processes to occur. Peat water from the storage tank is pumped using a push pump through the Microfilter/cartridge to the NF membrane (method 1). The NF pump used has a power of 350 watts, model SJ-60, with a suction power of 9 m, thrust of 38 m, and a maximum capacity of 42 L/ min or 2.5 m3/hour. The pressure in the NF membrane is 40 Psi, 60 Psi, and 80 Psi. Then the discharge of permeate (clean) and rejection (waste) water is produced. The calcium lactate solution injection process uses a dosing pump to carry water from the NF membrane. After passing through the calcium lactate solution, the treated water is taken with a sample bottle.

The same work step is carried out in treatment through the RO membrane (method 2). RO pressure: 40 Psi, 60 Psi, and 80 Psi, measured permeate (clean), and rejection or water discharge produced. The water pump booster used for RO was CNP model, type CDLF.2-11, power 1.1 Kw 1.5 Hp 220 V 1 Ph 2,950 R 50 Hz, capacity 2 m3/hour, and dimension for in-out pipe was 1.25 inch.

All analyses on initial samples and permeates were carried out at the West Kalimantan Provincial Health Office Laboratory. Next, a comparison was made of the results of processed peat raw water after processing with the addition of calcium lactate (C6 H10CaO6) and the membrane NF and RO process into drinking water with drinking water quality standards based on the Republic of Indonesia Minister of Health Regulation number 492 of 2010. The effectiveness formula calculated the percentage effectiveness of adding calcium lactate and the NF and RO membrane processes in reducing pollutant parameters in processing peat water into drinking water.

$$\% \, Effectiveness = \frac{|Inlet - outlet|}{Inlet} x100\%$$

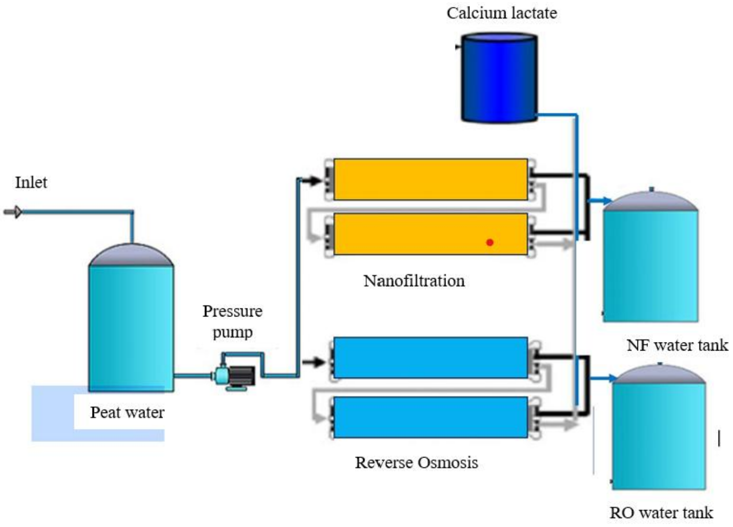

Figure 1. Schematic of the experimental setup

3. RESULTS AND DISCUSSION

Table 1 displays the comparison of water parameters before and after treatment using NF and 0.8 mg/l calcium lactate. The obtained results indicate that all the parameters comply with the standard requirements except for two, namely pH and color. The pH of the treated water was less than 6.5, which is still acidic for safe drinking purposes. Additionally, the color of the treated water remained at 29 throughout all treatment pressures. Figure 2 describes the difference in the color of the water before and after treatment. Figure 2(a) shows the dark watercolor before treatment, while after treatment using calcium lactate and RO, as shown in Figure 2(b), and nanofiltration, as shown in Figure 2(c), significant color changes are observed.

Table 1. Results of the NF and calcium lactate at various pressure

Analyzed parameter	Initial (mg/l)	Pressure (Psi)			Mean	Standard value for drinking water (mg/L)
		40	60	80		
E. coli	9.2	0	0	0	0	0
Total coliform	1,600	0	0	0	0	0
pH	5.78	5.8	6.5	6.2	6.1	6.5–8.5
TDS[1]	81	8.7	9.1	9.4	9.0	500
Turbidity (NTU)[2]	20	3.5	3.8	3.2	3.5	5
Color (TCU)[3]	509	28	30	29	29	15
Calcium	3.45	7.62	7.94	7.48	7.88	70

Note: [1]TDS=total dissolved solid; [2]NTU=nephelometric turbidity units; [3]TCU=true color units

In Table 2, the results of water treatment using RO and 0.8 mg/l calcium lactate with three different pressures are presented. The results indicate that the pH level remains a concern for RO performance, with an average value of 6.1 across the three pressure treatments. However, all other parameters met the standard value for safe drinking water.

Table 3 shows the comparative effectiveness of the two methods used in this study to meet the minimum standard for safe drinking water. The study found that both membrane technologies performed similarly in terms of efficacy. However, a slightly higher proportion of positive changes were observed with the RO method, especially in reducing TDS, turbidity, and color. Neither of the methods was able to raise the average pH to the standard value.

A recent study compared the use of calcium lactate as a coagulant with NF and RO membranes at various pressures to process peat water into safe drinking water. The study found that RO produced slightly better results than NF, with better rejection of all studied parameters. Another study found that NF removal efficiencies were similar to those achieved by RO membranes [18], [19]. However, the use of calcium lactate as a coagulant did not stabilize the average pH of the water according to the standard pH range of 6.5-8.5, due to initial concentration and pressure applied.

Table 2. Results of the RO and calcium lactate at various pressure

Analyzed parameter	Initial (mg/l)	Pressure (Psi)			Mean	Standard value for drinking water (mg/L)
		40	60	80		
E. coli	9.2	0	0	0	0	0
Total coliform	1,600	0	0	0	0	0
pH	5.78	5.6	6.5	6.1	6.1	6.5 – 8.5
TDS[1]	81	7.7	7.1	7.4	7.4	500
Turbidity (NTU)[2]	20	2.7	2.8	2.9	2.8	5
Color (TCU)[3]	509	8.6	8.7	8.9	8.7	15
Calcium	3.45	7.6	7.6	7.48	7.56	70

Note: [1]TDS=total dissolved solid; [2]NTU=nephelometric turbidity units; [3]TCU=true color units

Table 3. The average effectivity of declining or elevating the analyzed parameter between NF and RO after adding calcium lactate coagulant

Analyzed parameter	Initial (mg/l)	NF+calcium lactate		RO+calcium lactate	
		Effectivity performance (%)	Output	Effectivity performance (%)	Output
E. coli	9.2	100	-	100	-
Total coliform	1,600	100	-	100	-
pH	5.78	5.54	+0.32	5.54	+0.32
TDS[1]	81	88,89	-	90,86	-
Turbidity (NTU)[2]	20	82,50	-	86	-
Color (TCU)[3]	509	94,30	-	98,29	-
Calcium	3.45	28.41	+4.43	19.13	+4.11

Note: [1]TDS=total dissolved solid; [2]NTU=nephelometric turbidity units; [3]TCU=true color units

The experiment examined the effects of two water treatment methods on pH levels at various pressures: 40, 60, and 80 Psi. The study found that the most suitable pH level for safe drinking water was achieved at a pressure of 60 Psi, whereas the pH dropped to 6.2 at 80 Psi. Although other parameters remained consistent across all pressures, 60 Psi was deemed the optimal pressure for this water treatment facility. Research has demonstrated that adding calcium lactate to peat water can increase the pH level from 5.78 to an average of 6.1. While calcium lactate has coagulating properties, it only affects water with a pH between 5-7 [13], and other interventions are necessary to stabilize the pH at safe levels [20].

Adjustment of pH levels is critical as it affects the activity and growth of microorganisms. Soda ash (Na2CO3) is frequently employed to neutralize acids or bases. An experiment by Nazir *et al.* [21] revealed that soda ash elevated the pH value from 4.87 to 9.82, making it less corrosive and more balanced, which is crucial for drinking water. Additionally, soda ash can remove specific contaminants, such as arsenic and radium. Despite it is numerous benefits, soda ash can be intricate and challenging.

Although soda ash can help increase water pH, it is important not to overuse it as this can lead to excessively alkaline water [22]. Additionally, it may not be effective in treating certain types of water contamination. To fully purify water, other treatment methods may be necessary in conjunction with soda ash. A treatment plant that utilizes a combination of nanofiber membrane and molecularly imprinted polymers can increase the adsorbent dosage and temperature, resulting in a decrease in peat water pH from 2 to 10 [23]. However, while the color concentration in the output water from initial, NF, and RO treatments was similar, the NF outlet still exceeded the permitted limits. When combined with calcium lactate as a coagulant, RO provided slightly better results.

In this study, membrane technologies were successful in improving the quality of peat water in terms of biological parameters and organic matter, while color was better addressed through RO. Although the color was visually similar between NF and RO, as displayed in Figure 2, the result shows higher TCU from the NF outlet than RO. At a pressure of 40 Psi, the color met the allowable limits [24]. Despite the success of RO, Hafiz *et al*. [25] found that certain parameters such as TDS, conductivity, and chloride, sodium, and calcium concentrations still exceeded allowable limits for this method alone. When compared with other alternatives, the NF and O3-based oxidation process proved to be one of the best treatment methods for color removal. Therefore, in this study, the coagulation using calcium lactate had an impact on reducing color intensity.

The study also discovered that the combination of NF or RO membrane and calcium lactate is a promising coagulant-flocculant for removing suspended sediments from water [13], [17]. NF and calcium lactate eliminated TDS and turbidity at an average of 88.89% and 82.5%, respectively, while the RO membrane achieved 90.86% and 86%. Both membrane methods increase the performance after adding calcium lactate, as presented by a previous study with a color removal efficacy of 32% and increasing the pH from 7.95 to 8.05 [26], [27].

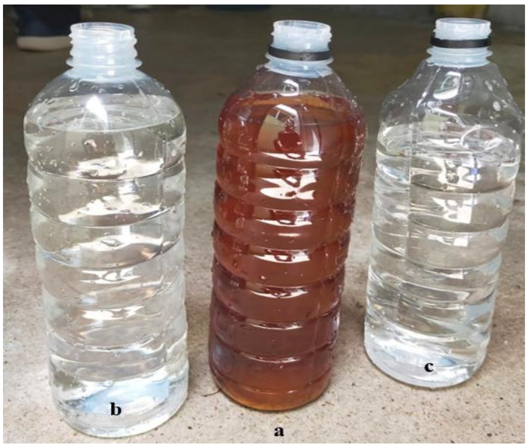

Figure 2. Visualization of peat water before and after treatment a) peat water pre-treatment, b) post calcium lactate+RO, c) post calcium lactate+NF

The experiment setup did not present any issues with bacteriological parameters. According to Table 3, the use of both membranes with calcium lactate resulted in a 100% reduction of *E. coli* and total coliform. This is of particular significance since the parameters met the minimum required standards for drinking water. NF and RO are commonly employed to eliminate pathogens: organic and inorganic contaminants found in drinking water [28], [29]. The study found that high pressure, specifically 60 Psi, was more effective in decontaminating feedwater with high osmotic pressure caused by an increase in the concentration of soluble substances.

While calcium lactate is a potential coagulant, it still needs to be combined with advanced technologies such as membrane methods, RO, and NF to provide safe drinking water. Although this study found that the combination with RO was more efficient in removing color intensity, it may be more expensive and require more energy. In contrast, the NF membrane is more sustainable and cost-effective since it consumes less energy and incurs fewer post-treatment expenses. However, achieving superior results for color removal with the NF membrane may require more advanced techniques such as oxidation [30].

This study provides valuable insights into the effectiveness of purifying water for drinking using calcium lactate in combination with NF and RO. However, there are a few limitations that should be noted for future research. Firstly, it may be beneficial to evaluate the results of using calcium lactate as a single coagulant before combining it with other advanced methods. This can help to minimize any bias resulting from the membrane's influence. Secondly, since the coagulant may pass through the filtration process, it is important to measure the output's calcium lactate dosage. This will enable us to determine if the dosage is still safe for drinking. Lastly, a more comprehensive study by measuring more analyzed parameters is important, such as iron (Fe) and other organic substances.

4. CONCLUSION

In conclusion, calcium lactate is recommended for stabilizing the pH level and suspended particles of peat water. The most effective approach for treating peat water is a combination of calcium lactate and RO rather than NF. Although RO can be more costly and energy-intensive, it remains the optimal choice. As such, it would be advantageous to develop a cost-effective water treatment plant that maximizes the use of membrane technology to achieve the best possible outcomes.

REFERENCES

[1] Directorate General of Disease Prevention and Control Ministry Health Republic of Indonesia, "Drinking water quality monitoring in 2022," 2023. [Online]. Available: https://p2p.kemkes.go.id/wp-content/uploads/2023/12/FINAL_231123_Layout_Pengawasan-Air-Minum_Bahasa-Inggris.pdf (Accessed: Oct 2, 2023).

[2] Directorate of Peatland Degradation Control, *Corrective action on peatland protection and management in Indonesia toward sustainable peatland management 2019-2020*. Jakarta: Ministry of Environment and Forestry Republic of Indonesia, 2021.

[3] Directorate of Peatland Degradation Control Ministry Health Republic of Indonesia, "Clean water amidst black water: a new oasis for peat communities," 2022. [Online]. Available: http://pkgppkl.menlhk.go.id/v0/wp-content/uploads/2023/03/Clean-Water-Amidst-Black-Water-New-Oasis-forr-Peatland-Communities-2.pdf (Accessed: Oct 2, 2023).

[4] M. Qadafi, D. R. Wulan, S. Notodarmojo, and Y. Zevi, "Characteristics and treatment methods for peat water as clean water sources: a mini review," *Water Cycle*, vol. 4, pp. 60–69, 2023, doi: 10.1016/j.watcyc.2023.02.005.

[5] M. Issaoui, S. Jellali, A. A. Zorpas, and P. Dutournie, "Membrane technology for sustainable water resources management: challenges and future projections," *Sustainable Chemistry and Pharmacy*, vol. 25, p. 100590, Apr. 2022, doi: 10.1016/j.scp.2021.100590.

[6] S. Jeong, G. Naidu, T. Leiknes, and S. Vigneswaran, "Membrane biofouling: biofouling assessment and reduction strategies in seawater reverse osmosis desalination," in *Comprehensive Membrane Science and Engineering*, E. Fontananova, E. Drioli, and L. Giorno, Eds., 2nd ed.Oxford, UK: Elsevier, 2017, pp. 48–71, doi: 10.1016/B978-0-12-409547-2.12261-9.

[7] R. A. A. Meena *et al.*, "Trends and resource recovery in biological wastewater treatment system," *Bioresource Technology Reports*, vol. 7, p. 100235, Sep. 2019, doi: 10.1016/j.biteb.2019.100235.

[8] I. Ivić *et al.*, "Influence of processing parameters on phenolic compounds and color of cabernet sauvignon red wine concentrates obtained by reverse osmosis and nanofiltration," *Processes*, vol. 9, no. 1, p. 89, Jan. 2021, doi: 10.3390/pr9010089.

[9] Y.-T. Shi, X. Meng, L. Yao, and M. Tian, "A full-scale study of nanofiltration: separation and recovery of NaCl and Na2SO4 from coal chemical industry wastewater," *Desalination*, vol. 517, p. 115239, Dec. 2021, doi: 10.1016/j.desal.2021.115239.

[10] L. Pino, E. Beltran, A. Schwarz, M. C. Ruiz, and R. Borquez, "Optimization of nanofiltration for treatment of acid mine drainage and copper recovery by solvent extraction," *Hydrometallurgy*, vol. 195, p. 105361, Aug. 2020, doi: 10.1016/j.hydromet.2020.105361.

[11] K. Norherdawati, W. M. Abdul, and R. S. A. Siti, "Iron and manganese removal by nanofiltration and ultrafiltration membranes: influence of pH adjustment," *Malaysian Journal of Analytical Science*, vol. 21, no. 1, pp. 149–158, Feb. 2017, doi: 10.17576/mjas-2017-2101-17.

[12] H. Jain, R. Dhupper, A. Shrivastava, and M. Kumari, "Enhancing groundwater remediation efficiency through advanced membrane and nano-enabled processes: a comparative study," *Groundwater for Sustainable Development*, vol. 23, p. 100975, Nov. 2023, doi: 10.1016/j.gsd.2023.100975.

[13] R. Devesa-Rey, N. Fernández, J. M. Cruz, and A. B. Moldes, "Optimization of the dose of calcium lactate as a new coagulant for the coagulation–flocculation of suspended particles in water," *Desalination*, vol. 280, no. 1–3, pp. 63–71, Oct. 2011, doi: 10.1016/j.desal.2011.06.051.

[14] C. Nioi, M. T. Lisanti, S. Lacampagne, P. Noilet, M. M. Peuchot, and R. Ghidossi, "Nanofiltration process as non-thermal alternative to thermovinification in Pinot noir winemaking," *OENO One*, vol. 54, no. 1, pp. 37–47, Jan. 2020, doi: 10.20870/oeno-one.2020.54.1.2507.

[15] Z. Zhang *et al.*, "Biofouling control of reverse osmosis membrane using free ammonia as a cleaning agent," *Journal of Membrane Science*, vol. 694, p. 122414, Feb. 2024, doi: 10.1016/j.memsci.2024.122414.

[16] I. Azreen, A. Y. Zahrim, S. H. Chong, and S. W. Ng, "Estimation of Melanoidin concentration in palm oil mill effluent ponding system and its treatment using calcium lactate," *IOP Conference Series: Materials Science and Engineering*, vol. 206, no. 1, p. 012078, Jun. 2017, doi: 10.1088/1757-899X/206/1/012078.

[17] R. Devesa-Rey, J. D. González-Aller, and S. Urréjola, "Analysis of biomaterials as green coagulants to control suspended solids for surface water treatment," *International Journal of Environmental Research and Public Health*, vol. 17, no. 5, p. 1777, Mar. 2020, doi: 10.3390/ijerph17051777.

[18] V. Yangali-Quintanilla, S. K. Maeng, T. Fujioka, M. Kennedy, Z. Li, and G. Amy, "Nanofiltration vs. reverse osmosis for the removal of emerging organic contaminants in water reuse," *Desalination and Water Treatment*, vol. 34, no. 1–3, pp. 50–56, Oct. 2011, doi: 10.5004/dwt.2011.2860.

[19] V. L. Kapepula *et al.*, "Evaluation of commercial reverse osmosis and nanofiltration membranes for the removal of heavy metals from surface water in the Democratic Republic of Congo," *Clean Technologies*, vol. 4, no. 4, pp. 1300–1316, Dec. 2022, doi: 10.3390/cleantechnol4040080.

[20] H. M. A.-S. Yehia and S. M. Said, "Drinking water treatment: pH adjustment using natural physical field," *Journal of Biosciences and Medicines*, vol. 9, no. 6, pp. 55–66, 2021, doi: 10.4236/jbm.2021.96005.

[21] R. bin Nazir, S. T. Amiri, and K. A. Kassim, "The effect of soda ash (Na2Co3) on pH and compaction characteristics of malaysian laterite soil," *Electronic Journal of Geotechnical Engineering*, vol. 18, pp. 2963–2968, 2013.

[22] M. Swaco, "Soda ash (sodium carbonate)," 2019. [Online]. Available: https://www.slb.com/-/media/files/mi/product-sheet/soda-ash-ps.ashx (Accessed: Oct 2, 2023).

[23] M. A. Zulfikar, I. Afrianingsih, M. Nasir, and N. Handayani, "Fabrication of a nanofiber membrane functionalized with molecularly imprinted polymers for humic acid removal from peat water," *Desalination and Water Treatment*, vol. 97, pp. 203–212, 2017, doi: 10.5004/dwt.2017.21443.

[24] N. N. Arifianingsih *et al.*, "Peat water treatment using oxidation and physical filtration system and its performance in reducing iron (Fe), turbidity, and color," in *E3S Web of Conferences*, Feb. 2020, p. 07011, doi: 10.1051/e3sconf/202014807011.

[25] M. Hafiz, A. H. Hawari, R. Alfahel, M. K. Hassan, and A. Altaee, "Comparison of nanofiltration with reverse osmosis in reclaiming tertiary treated municipal wastewater for irrigation purposes," *Membranes*, vol. 11, no. 1, p. 32, Jan. 2021, doi: 10.3390/membranes11010032.

[26] A. Y. Zahrim, Z. D. Dexter, C. G. Joseph, and N. Hilal, "Effective coagulation-flocculation treatment of highly polluted palm oil mill biogas plant wastewater using dual coagulants: decolourisation, kinetics and phytotoxicity studies," *Journal of Water Process Engineering*, vol. 16, pp. 258–269, Apr. 2017, doi: 10.1016/j.jwpe.2017.02.005.

[27] P. Chuntanalerg, S. Bureekaew, C. Klaysom, W.-J. Lau, and K. Faungnawakij, "Nanomaterial-incorporated nanofiltration membranes for organic solvent recovery," in *Advanced Nanomaterials for Membrane Synthesis and its Applications*, W. J. Lau, A. F. Ismail, A. M. Isloor, and A. Al-Ahmed, Eds., Amsterdam: Elsevier, 2019, pp. 159–181, doi: 10.1016/B978-0-12-814503-6.00007-0.

[28] R. Singh, R. Bhadouria, P. Singh, A. Kumar, S. Pandey, and V. K. Singh, "Nanofiltration technology for removal of pathogens present in drinking water," in *Waterborne Pathogens*, M. N. V. Prasad and A. Grobelak, Eds., Oxford, UK: Elsevier, 2020, pp. 463–489, doi: 10.1016/B978-0-12-818783-8.00021-9.

[29] A.-S. M. Aly, M. M. Kamel, A. Hamdy, K. Z. Mohammed, and M. A. Abbas, "Reverse osmosis pretreatment: removal of iron in groundwater desalination plant in Shupramant-Giza-a case study," *Current World Environment*, vol. 7, no. 1, pp. 23–32, Sep. 2012, doi: 10.12944/CWE.7.1.04.

[30] H.-H. Jang, G.-T. Seo, and D.-W. Jeong, "Advanced oxidation processes and nanofiltration to reduce the color and chemical oxygen demand of waste soy sauce," *Sustainability*, vol. 10, no. 8, p. 2929, Aug. 2018, doi: 10.3390/su10082929.

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