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Research Article

Pressure Effect on Turbidity, pH, Lead Content, and Coliform during the Demineralization Process of Brackish Water

Pengaruh Tekanan terhadap Kekeruhan, Ph, Kadar Timbal (Pb), Coliform selama Proses Demineralisasi Air Payau

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Abstract

Brackish water is a mixture of freshwater and seawater and typically exhibits intermediate physicochemical characteristics. Cilacap City is located in a coastal area, resulting in the mixing of freshwater from river systems with seawater intrusion, thereby producing brackish water with relatively high mineral content. Demineralization is a water purification method that can be applied to treat this type of water or wastewater, producing water with significantly reduced mineral content suitable for various uses. Therefore, this research aimed to investigate the effects of operating pressure on turbidity, pH levels, lead (Pb) concentration, and coliform content during the demineralization of brackish water. This research was carried out from March to June, and the sample of brackish water was obtained from the Northern Cilacap Payau Forest Tour Area. Purification method of demineralization process consists of the filtering of silica sand, zeolite adsorption, membrane filtration, and ion exchange with anion resin and cation resin repeatedly. The best result obtained was a pressure of 10 psi with a pH level of 5.9, decreasing turbidity of 90.81%, lead level content of 28.125%, and coliform bacteria of 55.49%.

Keywords: brackish water; demineralization; demineralized water; ion exchange; membrane filter.

Abstrak

Air payau memiliki sifat setengah dari air laut. Kota Cilacap bersandingan dengan laut sehingga air disekitar pesisir sungai bercampur dan terasa payau memiliki banyak mineral. Proses demineralisasi merupakan salah satu cara pemurnian air yang dapat digunakan dalam memurnikan air payau sehingga mampu dimanfaatkan sebagai air demineral. Penelitian ini dilakukan dengan tujuan untuk mengetahui pengaruh tekanan prototype demineralisasi air payau terhadap parameter kekeruhan, pH, kadar timbal, dan coliform. Air payau yang digunakan dalam penelitian ini didapat dari Wisata Hutan Payau Cilacap Utara. Penelitian dimulai dari bulan Maret hingga Juni. Metode pemurnian pada prototype demineralisasi terdiri dari filtrasi pasir silika, adsorpsi zeolit, filtrasi membran dan pertukaran ion dengan resin anion & kation berulang dua kali. Hasil penurunan parameter yang paling baik terjadi pada tekanan 10 psi dan pH 5,9 dengan efisiensi penurunan kekeruhan sebesar 90,81%, kadar timbal 28,125%, dan bakteri coliform sebesar 55,49%.

***Kata kunci**: air payau; air demineral; demineralisasi; pertukaran ion; filtrasi membrane.*

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1. Introduction

Water is essential for all human activities on Earth, as it supports daily functions across multiple sectors. Individuals, households, and industries alike depend on water to sustain their routine operations [1]. Different activities require water of varying quality standards. Laboratory applications, in particular, require highly purified water that is free from minerals, as it is used as a solvent, reagent, and for washing laboratory equipment. This applied research was carried out to investigate the utilization of brackish water, which was processed into demineralized water for use in laboratory activities. The use of brackish water was selected due to its abundant availability in Cilacap City, where the water is commonly found along riverbanks directly influenced by tidal seawater intrusion [2]. Brackish water is formed from the mixing of seawater and freshwater. The properties and characteristics of this water are generally similar to those of seawater. However, its mineral concentration is lower than that of seawater [3]. Salt, or salinity of brackish water ranges from 0.5 ppm to 17 ppm, with a rough water appearance [4]. It differs greatly in the characteristics of demineralized water, which is free of minerals and bacterial contaminants such as *E. coli* and coliform [5].

According to BSN [6], demineralization, deionization, distillation, and reverse osmosis are some of the processing methods that can be used in water purification processes. Demineralized water is often used in industrial and laboratory fields. Due to its low mineral content and anti-corrosive properties, demineralized water is commonly preferred to reduce equipment maintenance costs and enhance equipment durability [7]. To produce demineralized water, brackish water must undergo appropriate treatment processes to meet established quality standards. This research is a design of a prototype of demineralization equipment and an experiment conducted to determine the impact of pressure during demineralization of brackish water on turbidity, pH, lead (Pb) content, and coliform parameters.

2. Research Methods

2.1 Tools and Materials

Tools were used include an electric drill, wrench, screwdriver, saw, tongs, scissors, and cutter to support the assembly of the demineralization prototype. Meanwhile, tools were used in testing sample results include a Turbiditymeter, pH meter, and Atomic Absorption Spectrophotometer (AAS).

Brackish water was obtained from the Brackish Forest Tour, located in northern Cilacap. Physical properties of water are characterized by a brown color, indicating a relatively high salt content. Consequently, specialized treatment is required to produce mineral-free water [8].

This research was a prototype design used to process brackish water into demineralized water. The design process used AutoCAD software to obtain prototype designs that match the methods to be used. This research was conducted at the Laboratory of Environmental Pollution Control Engineering and the UPTD Health Laboratory in Purbalingga.

2.2 Prototype Demineralization

The tool used is a prototype unit of demineralization of sewage water consisting of several stages of processing

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methods, such as filtration, adsorption, and ion exchange, using pumps for suction and water flow pressure. Prototype used a filtering installation that connects the housing of the filter as a reaction process, where the media was filled according to their respective provision. The media used are silica sand, zeolite, a 1 µm membrane filter, and anionic resin of the quaternary amine type and cationic resins of the sulfonic acid type.

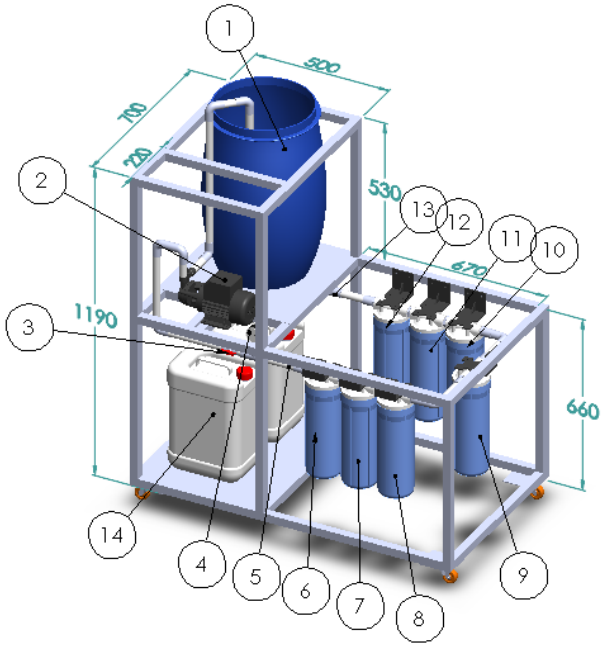

Figure 1. Demineralization of brackish water prototype

Information:
1. Initial storage tank
2. Water pump Shimizu PS-135
3. Ball valve
4. Pressure Gauge
5. Water installation (pipes)
6. Housing filter media silica sand 800 grams
7. Housing filter media zeolite 400 grams
8. Housing filter cartridge 1 µm
9. Housing filter media anion resin media 400 grams
10. Housing filter media cation resin media 400 grams
11. Housing filter media anion resin media 400 grams
12. Housing filter media cation resin media 400 grams
13. Output tap
14. Container

Researchers examined brackish water as a raw material for the production of demineralized water. To obtain high-quality demineralized water that meets established standards, an appropriate treatment system or method is required to convert brackish water into mineral-free water. Accordingly, a prototype brackish water treatment unit was developed, consisting of several processing stages (Figure 1). This demineralization prototype was made from a hollow iron frame shaped in the form of a cart, which consists of an initial storage tank, a suction and push pump. Then, a ball valve to regulate the pressure of water that comes out by examining the pressure gauge on the side, and seven filter housings sequentially containing each different media.

A sequence of media layout which consists of silica sand, zeolite, membrane filter, anion resin, cation resin, as well as anion resin and cation resin. Water flow path in the filter housing began with water entering the inlet port, after which the housing was filled. Water then passed through the filter cartridge gap containing the media through the lower opening, flows upward through the media, and exits through the outlet port. This process was repeated sequentially through each of the seven filter housings. The process water was stored in white jerry cans under the initial storage tank. Demineralized water intended for use must comply with established quality standards, as specified in Indonesian National Standard (SNI) 6241:2015.

2.3 Samplings of Method

Brackish water used as raw material for demineralized water was collected from the Brackish Forest Tourism area, with sampling conducted in the mid-zone

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among mangrove vegetation. This location was selected because, according to Naibaho et al [9], mangrove ecosystems are capable of reducing mineral content (salinity) in brackish water. The sampling of water was carried out by preparing a container in the form of a serigen and a sample-gathering device in the form of a shell. The tool was cleaned and rinsed with Aquadest to minimize contamination. The sampling point was taken at the center of the water surface, where there was no oil contamination forming the ceiling at the surface. A sample of 50 liters of water was taken for each experiment. Then a 24-hour deposit was carried out to lower the package of carried mud.

This research carried out three experiments, a demineralization prototype of brackish water used the pressure push from the pump that was varied by 30 psi, 20 psi, and 10 psi. The composition of the media was fixed on each experiment with 800 g of silica sand with a size of 110-150 mesh, 400 g of zeolite as an adsorbent with a size of 80-100 mesh, 1 µm of membrane filter, and 400 g of resin, quaternary amine, and cation resin sulfonic acid.

2.4 Analysis of the Sample

Water samples resulting from the trial of three different pressures were tested for turbidity based on SNI 06-6989.2502005, pH test carried out in line with SNI 6989.11:2019, testing of lead levels by AAS based on SNI 06-6989.8-24 in the Laboratory of DLH Cilacap [10]. The premise test (presumptive test) for coliform bacteria, carried out at the UPTD Health Laboratory Purbalingga. Based on the sample test results, the value of the decrease of each parameter can be obtained.

Table 1. The Result of turbidity test before and after demineralization

Input (NTU)	Pressure (psi)	Output (NTU)	Requirements (NTU) [11]
22	30	2.37	Max 1.5
22	20	2.32	Max 1.5
22	10	2.02	Max 1.5

Table 2. Value of pH level before and after demineralization

Input pH	Pressure (psi)	Output pH	Requirements [11]
8	30	7.5	5-7.5 or 4-5
8	20	6.5	5-7.5 or 4-5
8	10	5.9	5-7.5 or 4-5

3. Result and Discussion

3.1 Turbidity After Demineralization

The experiment was carried out by sampling the demineralization prototype of water at pressures of 30 psi, 20 psi, and 10 psi. The initial sample testing process was carried out during the test. Turbidity test ws measured with a turbiditymeter. The working principle is the same as the SNI 06-6989.2502005 test with a nephelometer, which was to calibrate the device with a solution that has a known value first, then insert the sample in a sample tube closed tightly, and clean the outer part of the tube [12]. The value of hardness against the hardness parameters is presented in Table 1.

Based on Table 1, the three experiments with a certain pressure experienced a significant decrease after being treated with the demineralization prototype. The hardness value of the water input showed a figure of 22 NTU. In the experiments with the highest drop value, it was at the pressure test of 10 psi, which was 19.98 NTU, or managed to reduce by 90,81% the hardness level of water. This

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result was influenced by the presence of pressure that pushes water toward silica sand and membrane filtration. According to Subagyo and Isworo [13], high operating pressure can decrease the filtration process, and thereby, low pressure will enhance the filtering process. In this process, the solid mud residues absorbed on the surface of the filter media will dissolve again if the pressure is high [14].

3.2 pH After Demineralization

The output pH value decreases as the pressure increases. This is because the rise of operating pressure leads to an increase in the concentration of H^+ in water [15]. pH value is influenced by the release of OH^- and H^+ that occurs in anion and cation resin in the process of demineralized water [16].

Based on Table 2, pH values have entered the standard range of demineralized water, with a pH value between 5-7.5. The rise in pH is due to the release of more H^+ ions than OH^- ions, influenced by pressure. The higher the ongoing process pressure that blocks the process flow, the faster the pH of the product will rise while the concentration of the hydrogen ion exchange H+ released decreases [15]. Zeolite medium on the prototype has no influence on the pH value. According to the research carried out by Trianah & Sani [17], a simple filtration experiment was conducted with zeolite against pH value, and found that pH values are always constant both before and after treatment. pH value is influenced by the release of OH^- and H^+ ions by the continuing anion (OH^-) and cation (H^+) resins. The higher the pressure of the ongoing process that inhibits the process flow, the faster the pH of the product will rise, while the concentration of the H^+ hydrogen ions released decreases.

3.3 Lead Concentration After Demineralization

Lead metal content in a measured input tank of 5.152 ppb is shown in Table 3. The values of the lead level of water input brackish water exceed the SNI limit of demineralized water by a maximum of 5 ppb. After treatment with demineralization of the prototype of brackish water, the rate of change drops to meet the specified limit of 3.703 ppb. The smallest lead level was at a 30 psi pressure test, with an efficiency of 28.125%. This is because high pressure facilitates the removal of lead from water by forcing it to be retained on the membrane filter used in the demineralization prototype [18]. The lead ion exchange process with resin, which takes place faster, can reduce lead metal minerals content, while if the flow pressure is slow and the process is long, the performance of the resin reaches the saturation point. As reported in the research by Said [19], lead metals can be effectively removed with resins. However, if the ion exchange process takes a long time, the levels of lead metallic minerals will decrease as the resin reaches saturation.

Table 3. Lead concentration before and after demineralization

Input (ppb)	Pressure (psi)	Output (ppb)	Requirements (ppb) [11]
5.152	30	2.914	Max 5
5.152	20	3.696	Max 5
5.152	10	3.703	Max 5

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3.4 Coliform Concentration After Demineralization

Coliform testing of demineralized water is conducted to determine the presence or absence of bacterial contamination in water. Based on Table 4, the coliform test on the sample of brackish water input detected the presence of 182 CFU/100 mL. Lower bacteria concentration was detected in each sample after the demineralization process. The smaller the pressure of water used, the lower the results of the test for coliform bacteria. At a pressure of 10 psi, only 81 colonies of coliform bacteria were detected. The longer coliform bacteria are absorbed by the filter membrane. Therefore, the slow pressure will catch the bacteria on the membrane in a very tight way because of the slow flow of water. Similarly, other studies have also shown that total coliform counts are affected by changes in pressure. The lower pressure, the longer water is forced through the membrane, which inhibits the growth of coliform bacteria, resulting in lower total coliform counts [18].

4. Conclusion

In conclusion, the optimal operating pressure for meeting SNI for demineralized water was found to be 10 psi, with a resulting pH of 5.9. Turbidity removal efficiency reached 90.81%. Higher operating pressure was found to reduce the effectiveness of the filtration process, whereas lower pressure enhanced filtration performance. Lead removal efficiency was 28.125%, which is attributed to the ability of high pressure to force lead ions to be retained on and accumulated in the membrane filter of the demineralization prototype. In addition, coliform bacteria removal efficiency was 55.49%, as lower water pressure facilitated the retention of bacteria on the membrane filter, thereby reducing the bacterial count in the treated water. To eliminate the presence of bacteria, ultrafiltration treatment is necessary to enable absorption into a smaller filter medium.

Table 4. Effect of pressure on coliform concentration

Input (CFU/100 mL sample)	**Pressure (psi)**	**Output (CFU/100 mL sample)**	**Requirements (CFU/100 mL sample)** [11]
182	30	167	Not Detected
182	20	121	Not Detected
182	10	81	Not Detected

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