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The Effect of Pre-Treatment Process on the Separation of Iron (Fe) and Manganese (Mn) Metals in Well Water in Lampoh Daya Banda Aceh City

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Abstrak

Groundwater is one of the primary sources of clean water supply and plays a vital role in meeting the needs of living organisms. However, groundwater quality often declines due to contamination by metals such as Iron (Fe), Manganese (Mn), and Total Suspended Solids (TSS), which exceed the quality standards established in the Regulation of the Minister of Health of the Republic of Indonesia No. 2 of 2023 on Clean Water Quality Standards. Excessive concentrations of Iron (Fe), Manganese (Mn), and TSS not only degrade the physical quality of water, causing changes in colour, odour, and taste, but also pose potential health risks, such as digestive disorders, tissue damage, and skin diseases. This study aims to determine the effect of the pre-treatment process and filter media thickness on reducing Iron (Fe) and Manganese (Mn) concentrations in healthy water in Lampoh Daya Village, Banda Aceh City. The research employed a laboratory experimental method with a quantitative approach. Well water samples were tested before and after treatment, which consisted of: (1) A pre-treatment process using coral stones and coconut fiber (ijuk) at a thickness of 45 cm, which produced the lowest concentrations at sampling point II, with Fe at 0.031 mg/L and Mn at 0.035 mg/L; and (2) A filtration process using coral stones, coconut fiber, activated carbon, and silica sand, which produced the lowest concentrations at a thickness of 90 cm at sampling point II, with Fe at 0.05 mg/L, Mn at 0.1 mg/L, and TSS at 2.4 mg/L. Based on the experimental results, the combination of the pre-treatment process and filter thickness can serve as an effective alternative solution for reducing Iron (Fe) and Manganese (Mn) concentrations in groundwater.

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Received: 04 November 2025	Pre-treatment process
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	Total Suspended Solids

1. Introduction

Pre-treatment process, filtration system, filter media thickness, well water, iron (Fe), and manganese (Mn). Water is an essential substance that plays a vital role in the daily lives of all living organisms.

More than 70% of Earth's surface is covered by aquatic regions, most of which are saline (oceans). Within the biosphere, water serves as a crucial component for sustaining life and maintaining its quality. It functions not only as a universal solvent but also as a medium that supports physiological processes, ecosystems, and biogeochemical cycles. The availability of high-quality water is directly correlated with a community's quality of life. Areas with adequate access to clean water tend to have higher living standards and better overall well-being (Arsyat, 2017).

Clean water production by regional water companies (PDAMs) often faces several challenges, including limited infrastructure and high operational costs. Consequently, many residents rely on dug wells as an alternative source of clean water and sanitation (Oriza Kahol et al., 2023). Based on the author's field survey, residents of Lampoh Daya Village, Jaya Baru District, primarily use healthy water for domestic and sanitation purposes. However, laboratory analysis shows that the healthy water contains Total Suspended Solids (TSS), Iron (Fe), and Manganese (Mn) levels exceeding the permissible limits set by Regulation No. 2 of 2023 of the Minister of Health. These issues are characterised by unpleasant odours, yellowish scale buildup around plumbing systems, and black sediment deposits in storage tanks.

According to Aulia (2021), the filtration method is a treatment process that separates solid particles from a fluid using filter media. Common filtration media employed in clean water treatment include coral stones or gravel, silica sand, coconut fibre (ijuk), activated carbon, and dacron. The use of filtration systems in water treatment installations provides many benefits, particularly by improving water quality by removing contaminants, reducing turbidity, and enhancing water's physical characteristics (Misa et al., 2019). Iron (Fe), or ferum, is a metallic element with a silvery-white appearance and atomic number 26. It contributes to water body discolouration when present in excess. Iron occurs in two forms: Fe^{2+} (ferrous), which is soluble, colourless, and typically found in oxygen-deficient (anaerobic) water, and Fe^{3+} (ferric), which forms yellowish to brownish precipitates upon exposure to oxygen. Excessive iron contamination can cause unpleasant odours, form oily films on water surfaces, and lead to health problems such as digestive disorders and skin diseases (Permatasari et al., 2018).

Manganese (Mn) is a reactive metal that readily combines with ions in water and air. It typically has a greyish-white colour, an atomic number of 25, and exists in various oxidation states, including Mn^{4+}. As a transition metal, manganese is hard and brittle, often appearing as a grey-white precipitate. Elevated concentrations of manganese (Mn) and iron (Fe) in water can cause health issues, unpleasant odours, and sediment buildup in piping systems and water storage tanks (Permatasari et al., 2018). (TSS).

This study presents a novel approach to improving groundwater quality by combining a pre-treatment process with variations in filter media thickness to effectively reduce Iron (Fe) and Manganese (Mn) concentrations in healthy water. While previous research has primarily focused on single-stage filtration or the use of individual filter materials, this study introduces an integrated two-step treatment system that uses locally available materials, such as coral stones and coconut fibre (ijuk) during the pre-treatment stage, followed by a multi-layer filtration system comprising silica sand and activated carbon. The research highlights the importance of optimising media thickness as a key operational parameter that significantly influences metal removal efficiency. This combination of simple, low-cost, and sustainable methods provides a practical alternative for communities that rely on groundwater, particularly in areas with limited access to centralised water treatment systems, such as Lampoh Daya, Banda Aceh. The findings contribute new insights into the design of decentralised water purification technologies suitable for rural and semi-urban environments in Indonesia.

2. Research Methodology

This study was conducted in West Lamteumen, with two sampling points: the first located at Jl. Batara II, and the second at Jl. Beutari V, Lampoh Daya, Jaya Baru District, Banda Aceh City. Sample testing was carried out at the Industrial Standardisation and Service Centre Laboratory (BSPJI) in Banda Aceh, while the research period lasted for six months, from February 2025 to July 2025.

a. Tools and Materials

The tools used in this study included a measuring tape, a grinding machine, and a hand drill. The materials consisted of PVC pipes (Type D, 4-inch and ¾-inch), 4-inch PVC caps, ¾-inch clean-out fittings, ¾-inch ball valves, ¾-inch nipple threads, ¾-inch female-thread elbows, ¾-inch tee unions, ¾-inch O-ring seals, PVC glue, ½-inch hoses, ¼-inch hose clamps, containers, coral stones, silica sand, activated carbon (from coconut shell charcoal), coconut fiber (ijuk), sample bottles, labels, and stationery.

b. Research Design and Sampling

This research employed a quantitative experimental method, focusing on the design and performance evaluation of a filtration unit system, which consisted of two stages:

a) The pre-treatment process is the preliminary stage.
b) Central filtration unit, serving as the primary filtering system.

Groundwater samples were collected from two different residential wells in Lampoh Daya Village. The first sampling point was located at Jl. Batara II, and the second at Jl. Beutari V. Filtered water samples were placed in labelled sample bottles corresponding to their sampling points, then transported to the laboratory for further analysis.

c. Laboratory Analysis Procedure

The experimental procedure involved testing the concentrations of Iron (Fe) and Manganese (Mn) using an Atomic Absorption Spectrophotometer (AAS). The testing process referred to Indonesian National Standard (SNI) 6989.84:2019, which specifies methods for determining Fe and Mn levels in water samples. The results obtained were compared with the Clean Water Quality Standards established in the Regulation of the Minister of Health of the Republic of Indonesia No. 2 of 2023 on water quality standards for hygiene and sanitation purposes. This comparison aimed to assess improvements in water quality before and after treatment using the pre-treatment process and the rapid filtration method.

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3. Results and Discussions

3.1 Initial Analysis of Well Water Quality

The results of the initial water quality analysis, conducted before the filtration process, were obtained from two sampling points (SA–TS I and SA–TS II). The study focused on the parameters of Iron (Fe) and Manganese (Mn) concentrations in healthy water. Sampling Point I (TS I) was located at Jl. Batara II, while Sampling Point II (TS II) was located at Jl. Beutari V, Lampoh Daya Village, Jaya Baru District, Banda Aceh City. These preliminary tests served to determine the groundwater baseline prior to the pre-treatment and filtration processes.

Table 1. Initial Analysis Results of Raw Well Water Quality

No.	Sampling Point	Parameter		Unit	Quality Standard
		Iron **(Fe)**	**Manganese (Mn)**		
1	I	1.2	0.8	Mg/L	0.2
2	II	0.8	1	Mg/L	0.1

Based on the data presented above, the results reflect the quality of raw well water before filtration. The raw water samples showed the highest Iron (Fe) concentration at Sampling Point I (TS I), at 1.2 mg/L, while the lowest Fe concentration was 0.8 mg/L at the same sampling point. Meanwhile, Manganese (Mn) recorded the highest concentration at Sampling Point II (TS II) at 1.0 mg/L, and the lowest at Sampling Point I (TS I) at 0.8 mg/L. The elevated concentrations of Iron (Fe) and Manganese (Mn) in the healthy water are influenced by several factors, including geological conditions, water chemistry, human activities, and seasonal variations. These factors contribute to the accumulation of metal ions in groundwater, leading to water quality that exceeds the Ministry of Health's permissible limits. The results of the initial well water quality analysis are illustrated in **Fig. 1**.

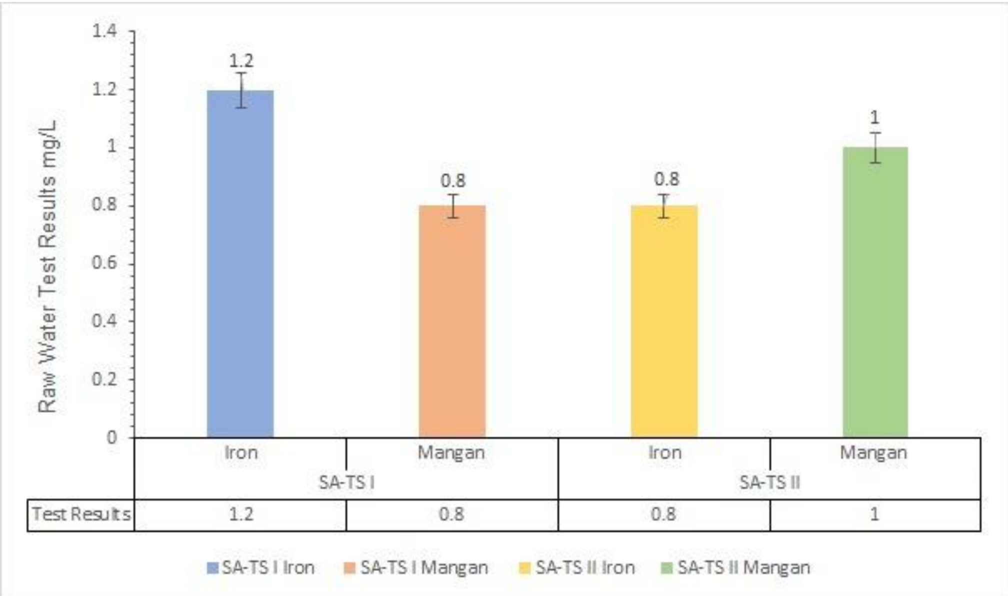


Fig. 1. Results of Well Water Quality Test Before the Treatment Process

Geologically, iron (Fe) originates from minerals within soil layers or rocks, typically found in the form of ferrous (Fe^{2+}) and ferric (Fe^{3+}) compounds. In this context, a tightly closed healthy structure can lead to oxygen-deficient (anaerobic) conditions in groundwater. Under such conditions, iron remains in a dissolved form (Fe^{2+}). However, when the water is pumped to the surface and exposed to oxygen, oxidation occurs, converting Fe^{2+} into Fe^{3+}. This oxidation process results in the formation of precipitates and gives the water a yellowish-brown colouration (Nuryana et al., 2019).

3.2 The Effect of the Pre-Treatment Process on Reducing Iron (Fe) and Manganese (Mn)

The pre-treatment process plays an essential role as the initial stage of water purification, reducing suspended solids and dissolved metal concentrations before the primary filtration. In this study, the pre-treatment unit used coral stones and coconut fibre (ijuk) as filtering media, with a thickness of 45 cm. The mechanism of removal during this stage primarily involved physical filtration and adsorption, during which coarse particles and a portion of the dissolved metals were trapped within the media layers. The results showed that after pre-treatment, the concentrations of Iron (Fe) and Manganese (Mn) decreased significantly compared with the raw water samples. At Sampling Point II, the Fe concentration decreased to 0.031 mg/L, while the Mn concentration dropped to 0.035 mg/L. This indicates that the pre-treatment process effectively facilitated the initial reduction in metal content, thereby improving the water's physical characteristics before entering the main filtration stage. The effectiveness of this process can be attributed to the porous structure of coral stones, which enhances sedimentation and mechanical filtration, and the fibrous texture of coconut fibre (ijuk), which acts as a natural adsorbent for metal ions. Together, these media form a simple yet efficient system for the preliminary treatment of groundwater, particularly suitable for household-scale applications in areas such as Lampoh Daya, Banda Aceh.

After pre-treatment (PT), well water samples from Sampling Point I (TS I) and Sampling Point II (TS II) were analysed. The pre-treatment unit used coral media 15 cm thick and coconut fibre (ijuk) 30 cm thick. Sampling analysis was carried out at two locations: TS I, located on Jl. Batara II and TS II, located on Jl. Beutari V, Lampoh Daya Village, Jaya Baru District, Banda Aceh City.

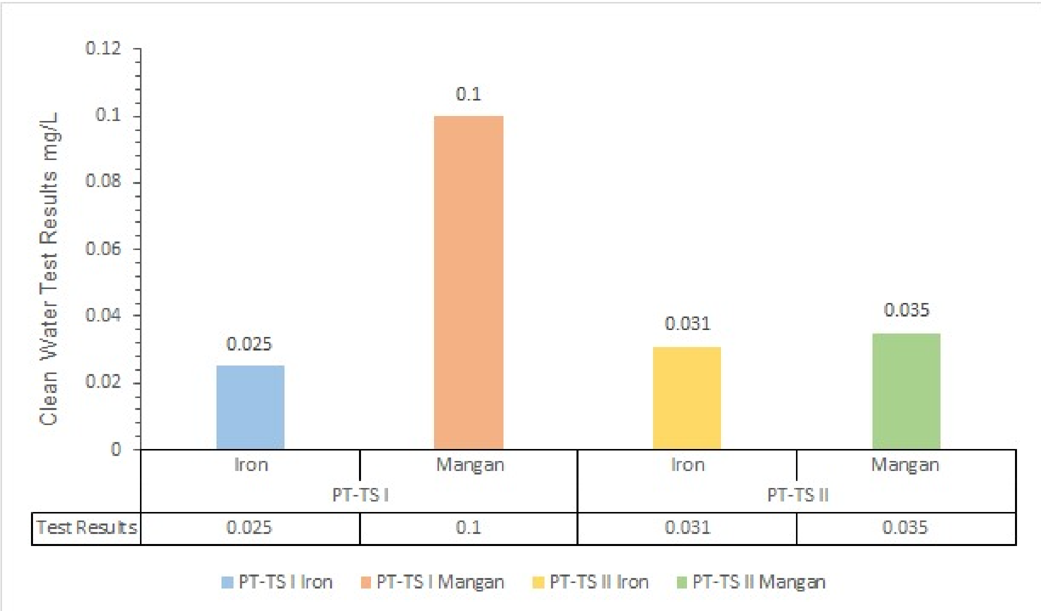


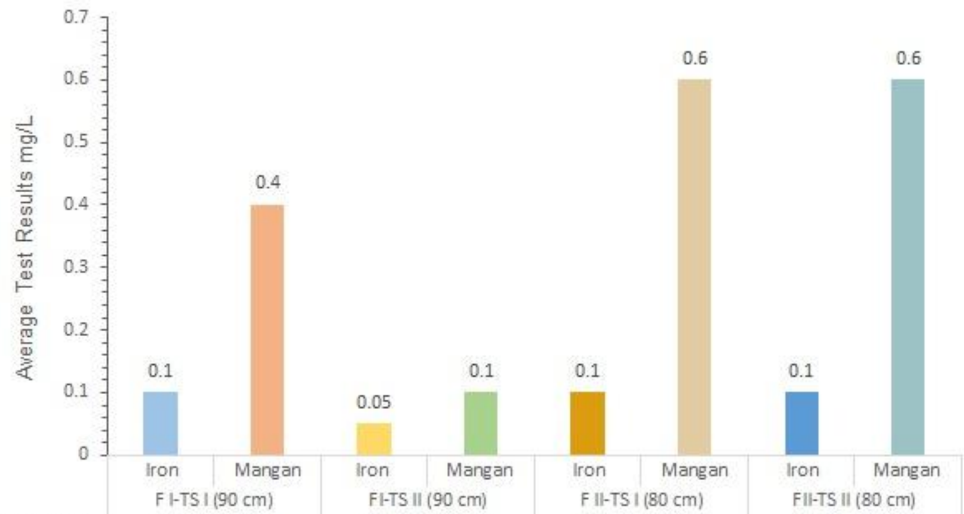
Fig. 2. Results of Well Water Testing During the Pre-Treatment Process at Sampling Points I and II

Fig. 2 illustrates the test results for healthy water after pre-treatment (PT). The concentration of Iron (Fe) showed the highest value at Sampling Point II (TS II), reaching 0.031 mg/L, while the lowest concentration was recorded at Sampling Point I (TS I) with 0.025 mg/L. Meanwhile, the concentration of Manganese (Mn) reached its highest level at Sampling Point I (TS I) at 0.10 mg/L and its lowest at Sampling Point II (TS II) at 0.035 mg/L. These results indicate that the pre-treatment process effectively reduced both Fe and Mn concentrations, although variations were observed between the two sampling points due to differences in well characteristics and local hydrogeological conditions.

3.3 The Effect of Filter Media Thickness on Reducing Iron (Fe) and Manganese (Mn) Concentrations

The thickness of the filter media plays a crucial role in determining the filtration process's efficiency in reducing dissolved metal concentrations, such as Iron (Fe) and Manganese (Mn). In this study, the filtration unit was designed with varying media thicknesses of 45 cm, 60 cm, and 90 cm to evaluate their effectiveness in improving water quality after the pre-treatment stage. The filtration system consisted of coral stones, coconut fibre (ijuk), activated carbon, and silica sand, arranged in layers to enhance both physical and chemical filtration. The results demonstrated that increasing the thickness of the filter media significantly improved the removal efficiency of Fe and Mn. The lowest concentrations were observed at the 90 cm filter thickness, particularly at Sampling Point II (TS II), where Fe levels decreased to 0.05 mg/L and Mn levels to 0.1 mg/L. This finding indicates that thicker filter media provide a longer contact time between the water and the filtration materials, allowing greater adsorption and oxidation.

Overall, the results confirm that media thickness optimisation is an essential factor in the design of effective filtration systems. The use of locally available materials, such as coral stones, silica sand, coconut fibre, and activated carbon, combined with appropriate media thickness, offers a practical, low-cost solution for reducing metal contaminants in groundwater, particularly for domestic-scale applications in areas such as Lampoh Daya, Banda Aceh. After filtration, well water samples from Sampling Point I (TS I) and Sampling Point II (TS II) were analysed. The filtration unit employed a combination of coral stones, coconut fibre (ijuk), silica sand, and activated carbon as filter media. Sampling and analysis were conducted at two locations: TS I, located on Jl. Batara II and TS II, located on Jl. Beutari V, Lampoh Daya Village, Jaya Baru District, Banda Aceh City.



	F I-TS I (90 cm)		FI-TS II (90 cm)		F II-TS I (80 cm)		FII-TS II (80 cm)	
	Iron	Mangan	Iron	Mangan	Iron	Mangan	Iron	Mangan
Test Results	0.1	0.4	0.05	0.1	0.1	0.6	0.1	0.6

Fig.3. Results of Well Water Testing After Filtration Using 90 cm and 80 cm Filter Media Thickness at Sampling Points I and II

Fig. 3 illustrates the results of well water testing after the filtration process using filter media with thicknesses of 90 cm and 80 cm. For the 90 cm filter (Filter I), the highest Iron (Fe) concentration was recorded at Sampling Point I (TS I), at 0.1 mg/L, while the lowest was observed at Sampling Point II (TS II), at 0.05 mg/L. The concentration of Manganese (Mn) was highest at Sampling Point II (TS II) at 0.1 mg/L and lowest at Sampling Point I (TS I) at 0.04 mg/L. For the 80 cm filter (Filter II), the highest Iron (Fe) concentration was 0.1 mg/L, observed at both Sampling Points I and II. Meanwhile, the Manganese (Mn) concentration reached 0.6 mg/L at both sampling points (TS I and TS II). These results indicate that increasing filter media thickness enhances the removal efficiency of Fe and Mn up to an optimal level (90 cm). However, a slight reduction in thickness (80 cm) led to higher Mn concentrations, suggesting that contact time and media depth play critical roles in adsorption and oxidation during filtration.

4. Conclusion

The results of the well water quality analysis showed that at Sampling Point I (TS I), the concentrations of Iron (Fe) and Manganese (Mn) were 1.2 mg/L and 0.8 mg/L, respectively, while at Sampling Point II (TS II), Fe and Mn concentrations were 0.8 mg/L and 1.0 mg/L, respectively. The application of a pre-treatment process using coral stones and coconut fibre (ijuk) proved effective in reducing Fe, Mn, and TSS levels in healthy water. After pre-treatment, Fe and Mn concentrations at TS I decreased to 0.025 mg/L and 0.1 mg/L, while at TS II, the concentrations were 0.031 mg/L and 0.035 mg/L, respectively. Furthermore, the filter media thickness significantly influenced metal removal efficiency. The 90 cm filter (F I) demonstrated the highest effectiveness, yielding the lowest Fe and Mn concentrations at TS II 0.05 mg/L and 0.1 mg/L, respectively, whereas the 80 cm filter (F II) showed higher concentrations, with Fe at 0.1 mg/L and Mn at 0.6 mg/L at TS I. Overall, the combination of pre-treatment and an optimised filter media thickness effectively improved well water quality by significantly reducing Fe and Mn levels, making it a practical alternative for community-scale water treatment in Lampoh Daya, Banda Aceh.

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