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Salt Revolution: A Smart Solution to Meet The Needs of The Petroleum Industry By Refining Rock Salt Through Innovative Abstersion Methods

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ABSTRACT - The need for salt in the petroleum industry is very high, especially in drilling. This significant demand is different from salt production. Effective, low-cost, and environmentally friendly technology to produce salt of the appropriate quality is still a challenge in the petroleum industry. On the other hand, the amount of rock salt produced by salt farmers reaches 28 million tons per year. This research utilizes rock salt from salt farmers. It converts it into quality salt according to the needs of the petroleum industry by using a modified mixing washer method to increase NaCl purity and reduce impurity levels such as Ca^{2+} and Mg^{2+} ions. The results showed that rock salt was successfully converted into industrial-grade salt using the modified abstersion method with a mixer washer tool. The characteristics of the salt produced after the mixing washer are that it has a whiter and cleaner color than premium and rock salt. Mixer washer salt has a concentration of 98.80% NaCl, 0.064% Ca^{2+}, and 0.062% Mg^{2+}, meeting the standard for petroleum industry-grade salt and suitable for use in the drilling process.

Keywords: petroleum industry, drilling process, environmentally friendly technology, improving salt quality, innovation technology.

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INTRODUCTION

The petroleum industry requires salt in its operations. Globally, the petroleum industry uses about 5-10 million tons of salt per year (Behera & Sangwai 2020; Kadyrov et al. 2020). An average oil well requires about 1,000-3,000 tons of salt during its drilling and completion period (Gaurina-Međimurec et al. 2024). Sixty to seventy percent of the total salt used in the petroleum industry is allocated to drilling mud (Alli 2019; Riyono et al. 2017; Sugihardjo 2020). The functions of salt in the drilling process include reducing hydrolysis and clay release in shale formations, increasing the specific gravity of drilling mud, and acting as an inhibitor to prevent unwanted chemical reactions between the mud and geological formations (Li et al. 2020; Tan et al. 2024).

The salt concentration in drilling mud is 2-10% by weight of the total mud (Oseh et al. 2023). However, this demand for salt differs from the production of salt of a quality suitable for use in the petroleum industry. The quality of salt required in the petroleum industry is reported to have a NaCl purity of 95-98%, with maximum impurities of Ca^{2+} and Mg^{2+} at 0.1% and 0.05%, respectively (Panagopoulos, 2022; Tripathi et al. 2023). Effective technology is needed to produce salt that meets the needs of the petroleum industry.

Current technologies used to produce high-purity salt include recrystallization, membrane, abstersion, and vacuum evaporation. Recrystallization is reported to be able to produce NaCl purity of 99.7% but has the disadvantage of relatively large energy consumption and relatively longer process time (Culcasi et al. 2022). The membrane is reported to be able to produce NaCl purity of 99.5% but requires high energy costs and membrane maintenance (Fajardo-Diaz et al. 2022). Vacuum evaporation produces NaCl purity of 99.8% but requires high initial costs and complicated maintenance (Kim et al. 2021).

Abstersion technology is in high demand because it is low-cost, environmentally friendly, and simple in its operating process compared to other technologies. Abstersion technology is reported to produce NaCl with a purity of 95-97% (Farhan Ullah Khan et al. 2021; Galvis-Sánchez et al. 2013; Han et al. 2014). The use of saturated old water in the Abstersion process is reported not to dissolve NaCl, except for a relatively small amount (1-2%) (Farahmand et al. 2009; Farhan Ullah Khan et al. 2021).

The commonly used abstersion technology employs a screw classifier that works in the counter current (Steenweg et al. 2021). The screw classifier abstersion technology is reported to be less effective, as it can only wash materials that are not bound to salt crystals. Therefore, it is necessary to modify the equipment used to increase the effectiveness of the abstersion process.

On the other hand, rock salt produced by salt farmers using the technique of evaporating seawater with sunlight reaches 28 million tons per year (Metwally et al. 2022; Prabawa & Bramawanto 2021; Xu et al. 2020). Due to its large quantity, the potential for utilizing rock salt in the petroleum industry is significant. Therefore, this study aims to convert rock salt into industrial-quality salt that meets the needs of the petroleum industry.

The mixing washer tool is a solution developed by researchers to overcome problems in the abstersion process. This tool is equipped with a stirrer, set at a specific speed, and placed in the center of the mixer tube. Additionally, bearings are installed on the walls of the mixer tube to create a turbulence effect from the stirred solution. Channels for the entry of old water and the exit of slurry and filtrate from abstersion are also installed on the walls of the tool. The component percentages in the salt produced from the modified mixing washer process will be compared with those in rock and premium salt.

Based on the above background, this research provides a solution to overcome the considerable need for salt in the petroleum industry by utilizing rock salt. The method used to improve the quality of rock salt is a modified abstersion method with a mixer washer. Some parameters observed in this study include the characteristics of the salt produced, the percent purity of NaCl, and the reduction of Ca^{2+} ions and Mg^{2+} ions.

METHODOLOGY

Materials

This study used rock salt from Pati Regency, Central Java, Indonesia, and premium salt from PT. Anta Krista Karisma in Indonesia. Table 1 presents the preliminary test results showing the NaCl, Ca^{2+}, and Mg^{2+} content of the two types of salt.

Table 1
Components in rock and premium salt

Salt type	Components (%)		
	NaCl	Ca^{2+}	Mg^{2+}
Rock	88.26	0.1920	0.1258
Premium	94.35	0.1279	0.1106

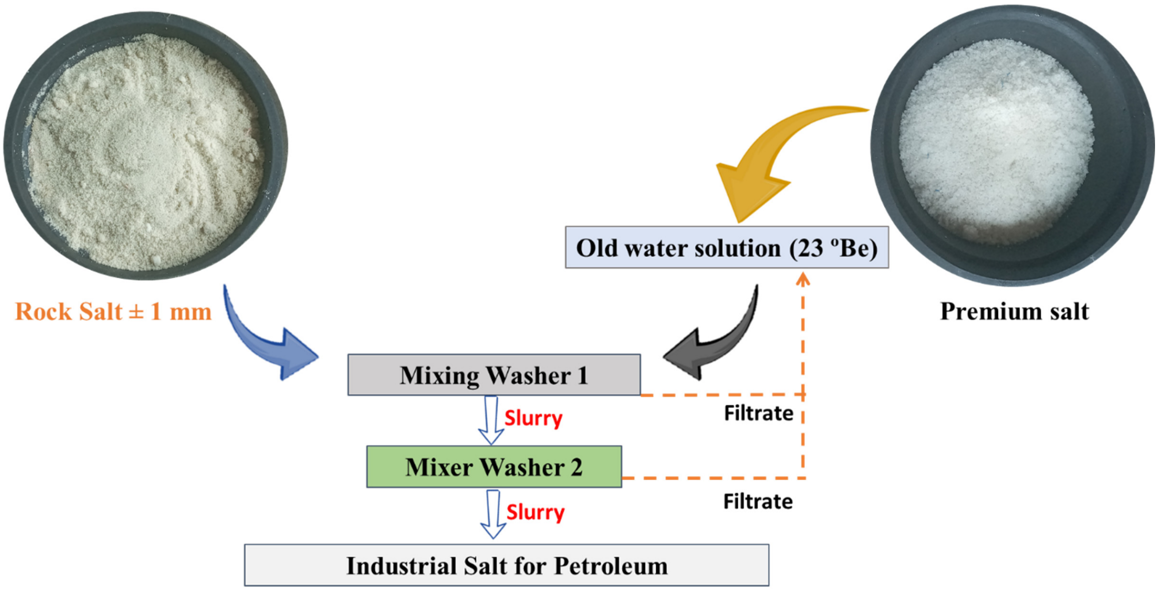

Figure 1
Schematic of crude salt purification by modified abstersion method

Rock salt abstersion method

The rock salt abstersion process was done using a modified previous research method (Widjaja et al. 2019). The modification is the addition of a mixer washer that is sustainable in the washing process so that it is more effective in increasing the purity of NaCl and reducing the levels of Ca^{2+} and Mg^{2+} ions (Figure 1). A total of 35 kilograms of rock salt was ground to a size of about 1 mm to increase the surface area, making the NaCl purification process more effective. The pulverized salt was then gradually fed into the first washing machine containing old water, stirring at 50 rpm. The slurry from the first abstersion was then transferred to the second washing machine, including old water, and stirred at 200 rpm. The old water was prepared by dissolving premium salt in water at a ratio of 1:3, resulting in a Baume degree of 23 °Be, which, according to previous research, is optimal for salt abstersion. This study used about 105 liters of old water, adjusted to the capacity of the washing machine. The old water was pumped into the washing machine. The abstersion process in each machine lasted 60 minutes, with filtrate and slurry collected every 10 minutes to analyze NaCl, Mg^{2+}, and Ca^{2+} levels.

Component and characteristic analysis of salt

This study's salt components analysis included NaCl, Mg^{2+}, and Ca^{2+} ions using an atomic absorption spectrophotometer (AAS) (Mohammed 2024). The first step was to prepare calibration solutions for Na, Mg, and Ca. A total of 10.0 ml of each Na, Mg, and Ca solution, with a concentration of 1000 mg/L, was transferred into separate 1000 ml volumetric flasks. Each flask was filled to the mark with deionized water, and the resulting solutions were stored in polyethylene bottles. Next, 1, 2, 5, 10, 15, 20, 40, and 50 ml of working standard solution with a concentration of 10 mg/L were pipetted into eight 100 ml volumetric flasks. One ml of Cs-La solution was added to each flask and diluted to the mark with deionized water to obtain concentrations of 0.1, 0.2, 0.5, 1.0, 1.5, 2.0, 4.0, and 5.0 mg/L. A blank solution was prepared by diluting 1 ml of Cs-La solution to 100 ml. All calibration solutions and blanks were stored in polyethylene bottles and prepared on the analysis day. A 10 ml sample was transferred into a test tube, and 100 µl of Cs-La solution was added using a micropipette and mixed thoroughly to analyze Na, Mg, and Ca levels. The absorption signals were measured at wavelengths of 589.6 nm (Na), 285.5 nm (Mg), and 422.7 nm (Ca) using a spectrophotometer, and calibration graphs determined the concentrations in the samples. This study also reviewed the characteristics of the salt produced using a Keyence VHX-7000 digital microscope.

RESULTS AND DISCUSSION

Salt characteristics

The appearance of the salt before and after the abstersion process is shown in Figure 2. Rock salt has a brownish color, indicating the presence of impurities. Previous studies have reported that impurities in rock salt include soil, dust, minerals, and microorganisms (Ercoşkun, 2023; Susilowati et al., 2023). These impurities remain due to the evaporation, crystallization, and filtration processes that do not entirely remove them. Premium salt has a whiter and cleaner color than rock salt, resulting from a better refining process with fewer impurities. The source of raw materials differs: premium salt is often produced from pure sea salt or well-preserved underground deposits. In contrast, rock salt comes from sea salt collected from unprotected locations or through less selective collection methods. Salt produced by the mixing washer process has a whiter and cleaner color than premium and rock salt.

Figure 2
Salt appearance: A) rock salt, B) premium salt, and C) mixing washer salt.

NaCl purity

NaCl purity is an essential indicator in determining the quality of the produced salt. Figure 3 shows the percentage of NaCl concentration in rock salt before and after going through the mixing washer. The rock salt has a NaCl percentage of 88.26%, indicating that it contains about 12% impurities. Additionally, this percentage suggests that the rock salt does not meet the petroleum industry salt standard. Other studies report that the NaCl concentration in petroleum industrial salt is around 95-98% (Wagner et al. 2021; X. Zhang et al. 2021). A modified abstersion method with a mixing washer can increase the NaCl concentration from 88.26% to 97.71%. The longer the stirring and abstersion time of rock salt in the mixing washer, the higher the percentage of NaCl produced, reaching up to 98.80%. This result shows that longer stirring and abstersion times allow all rock salt particles to be thoroughly washed with old water, resulting in a high NaCl percentage. The addition of bearings to the mixing washer increases the collision between particles. Gradual abstersion at low speed followed by high speed effectively removes impurities from the salt. Moreover, this increase in NaCl concentration demonstrates that the mixing washer can convert rock salt into industrial salt suitable for the petroleum industry.

Impurity reduction

Another indicator of salt quality is the deficient impurities such as Mg^{2+} and Ca^{2+} ions. Previous studies reported that salt for the petroleum industry should have Mg^{2+} and Ca^{2+} ion concentrations below 0.05% and 0.1%, respectively (Alameen et al., 2023; Almousa et al., 2023; L. Zhang et al., 2024). The crude salt has Mg^{2+} and Ca^{2+} concentrations that are still above the petroleum industry salt standards (Table 1). A mixing washer reduced Ca^{2+} from 0.192% to 0.064% and Mg^{2+} from 0.1258% to 0.062% (Figure 3). The significant decrease in Ca^{2+} and Mg^{2+} ions shows the effectiveness of the mixing washer. Up to the 10th minute, the abstersion process resulted in Ca^{2+} concentrations below the petroleum industry salt threshold. From the 20th to the 60th minute, there was a 50% decrease in Ca^{2+} concentration. This result shows that after 10 minutes, impurities such as Ca^{2+} can be thoroughly washed out with the old water, thus reducing their concentration. However, the Mg^{2+} concentration remained above the standard threshold for petroleum industry salt until the 60th minute. This result may be because the aged water reacted with Ca^{2+} ions first compared to Mg^{2+}. Old water saturated with Ca^{2+} reduces the effectiveness of leaching against Mg^{2+}. This explanation is supported by research that reports that the size of Ca^{2+} ions is larger than that of Mg^{2+}. These results indicate that the modified mixing washer effectively reduces Ca^{2+} and Mg^{2+} ions from rock salt.

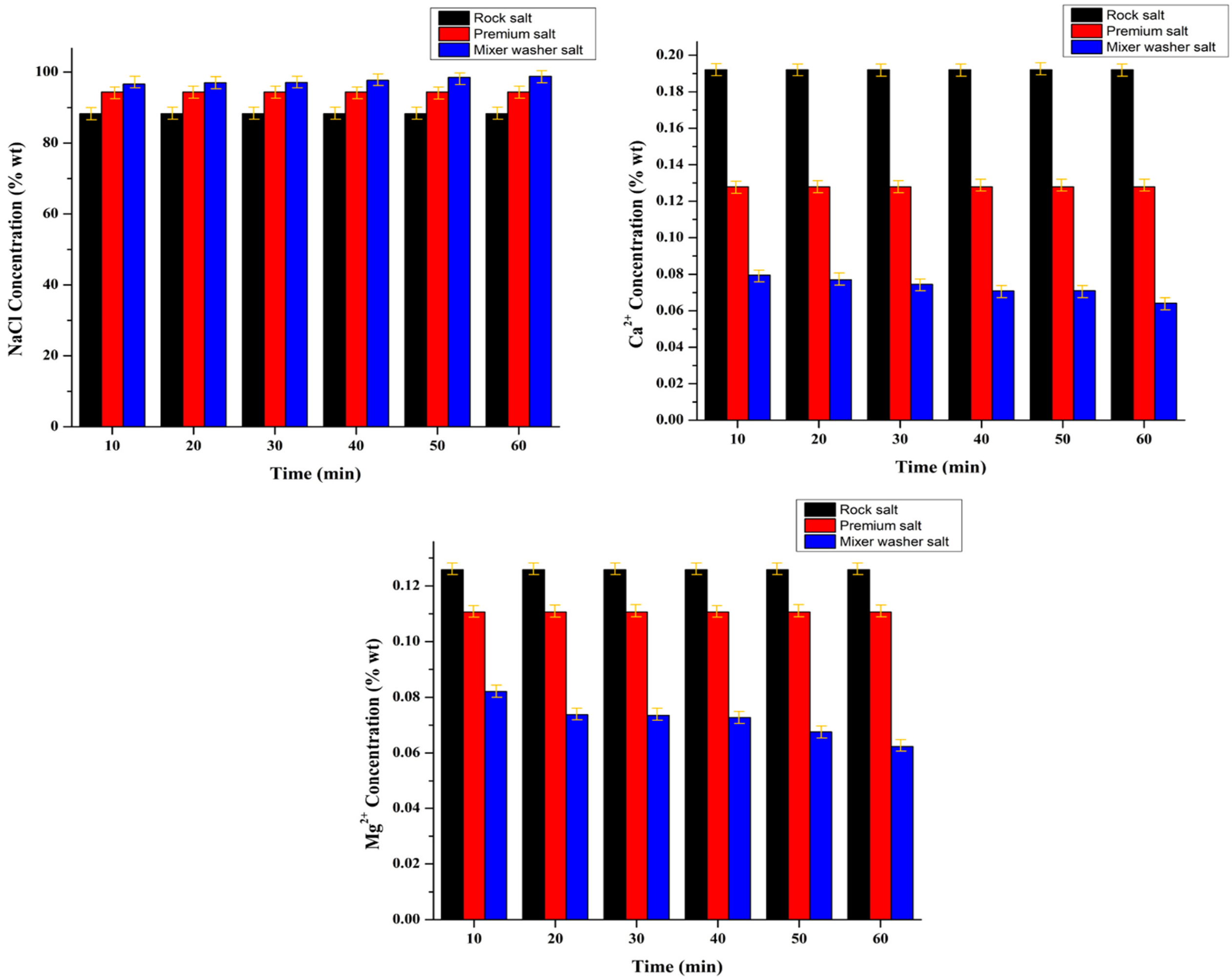

Figure 3
Comparison of salt components before and after the abstersion process

CONCLUSION

This study successfully produced petroleum industrial-grade salt from coarse salt using a modified abstersion method with a mixing washer. The salt produced has a whiter and cleaner color compared to premium and coarse salt. Salt from the mixing washer has a NaCl concentration of 98.80%, Ca^{2+} 0.064%, and Mg^{2+} 0.062%, meeting the petroleum industry salt standards and suitable for use in the drilling process.

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GLOSSARY OF TERMS

Symbol	Definitions	Unit
NaCl	Natrium klorida	
Ca^{2+}	Ion kalsium	
Mg^{2+}	Ion magnesium	
AAS	Atomic absorption spectrophotometer	
mg/L	miligram/liter	
Cs-La	Cesium-Lantanum	
µL	Mikro liter	
°Be	Baume degree	
rpm	Revolution per minute	
nm	Nanometer	

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