Contents list available at CBIORE journal website

Journal of Emerging Science and Engineering

Journal homepage: https://journal.cbiore.id/index.php/jese/index

Research Article

The laboratory study of P441 oil samples separation by using super absorbent polymer from the waste diapers

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Abstract. The waste diapers, the second largest waste source after plastic, pose environmental challenges due to their slow degradation of 25-50 years. Reprocessing diaper waste, including utilizing Super Absorbent Polymer (SAP), is crucial. SAP's high absorption capacity aids in research for separating crude oil from water, particularly relevant for Indonesian oil wells with aging infrastructure. Emulsions in crude oil, stabilized by natural chemicals, require demulsification to prevent production issues, underscoring the importance of efficient water-oil separation methods. The research experimentally compares oil-in-water emulsion separation using SAP with and without SAP. The study utilizes waste-based ingredients like used diapers, and tests involve centrifuge processes at varying temperatures. SAP's osmotic properties enable high water absorption, impacting demulsification efficiency. This study investigates the impact of temperature on emulsion separation between water and crude oil. Testing at 26°C and 40°C reveals accelerated separation at higher temperatures due to reduced crude oil viscosity. Waste-containing tubes demonstrate better separation, with SAP absorbing water, enhancing separation efficiency. Increasing centrifuge speed and temperature improve oil-water separation, showcasing SAP's effectiveness in waste management processes. Research findings on crude oil-water separation using diaper waste conclude that demulsification is faster at 40°C due to decreased viscosity; with SAP waste, volumes of water are more efficient at 40°C; SAP's hydrophilic nature traps water in the gel network; SAP enhances separation effectiveness compared to non-SAP methods in saline solutions.

Keywords: Demulsification, Super Absorbent Polymer, Diapers, Waste, Polymer

Received: 18th June 2025; Revised: 7th Oct 2025; Accepted: 8th November 2025; Available online: 16th November 2025

1. Introduction

After plastic trash, disposable diapers are the second greatest source of waste. Disposable baby diapers are always discovered as a consequence of inspections at temporary and ultimate landfills. The usage of disposable newborn diapers is increasing in parallel with the high birth rate (Ernyasih et al., 2023; Glinka et al., 2024). In Indonesia, disposable baby diapers are used by 97.1% of the population. Meanwhile, the time required to degrade newborn diaper waste is extremely long, estimated to be 25-50 years (Salima, 2023). As a result, reprocessing baby diaper waste is critical. One method is to use the waste from baby diapers as a separator between crude oil and water (Aditya et al., 2022; Sahi et al., 2019). Super Absorbent Polymer (SAP) is used on the interior. Because of their strong absorption capabilities, materials like these play a significant part in the research process for separating crude oil from water (Kiatkamjornwong, 2007; Zekry et al., 2020). According to the condition of Indonesian oil wells, which are growing older and have a significant quantity of water cut on average (Doust & Noble, 2008). The general nature of petroleum is closely related to the specific gravity (SG) value (Santos et al., 2014). SG in this petroleum ranges from 0.8–1 (Kotzakoulakis & George, 2017). The amount of SG for each crude oil is closely related to the structure of the hydrocarbon molecule, the sulphur content, and the nitrogen content (Hsu & Robinson, 2019). The smaller the SG of petroleum, the greater the number of light products it will produce and vice versa (Elgowainy et al., 2014). Table 1 show the classification of SG for crude oil.

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https://doi.org/10.61435/jese.2025.e31
ISSN: p-ISSN: 3026-0817; e-ISSN: 3026-0183.The Author(s). Published by CBIORE

Table 1
Specific gravity classification for crude oil (Al-Dahhan & Mahmood, 2019)

Crude Oil	Specific Gravity
Light	< 0.830
Medium-Light	0.830 – 0.850
Heavy-Light	0.850 – 0.865
Heavy	0.865 – 0.905
Super-Heavy	>0.905

The characteristics of crude oil are very influential in the stability of the emulsion (Wong et al., 2015). Therefore, it is necessary to know the characteristics and stability of the emulsion from the crude oil to know the right process for processing at a later stage. The process of separating water from crude oil emulsion can be done by mechanical, heat, electrical, and chemical methods (Saad et al., 2019; Zolfaghari et al., 2016). Among the four methods, there is one method that can produce high-efficiency values, namely the chemical method. Therefore, the chemical method in the process of separating water from crude oil emulsions is very much carried out in the petroleum industry by combining two methods, such as separating using the chemical method and the heat method, because it can increase the efficiency of water separation in crude oil (Kokal, 2005; Sari & Sauqi, 2020).

Oil and gas emulsions are defined as a system consisting of two immiscible liquid phases, in which one of the liquid phases is dispersed in the other liquid (Goodarzi & Zendehboudi, 2019; Wong et al., 2015). The liquid which is broken down into grains is called the dispersed phase, while the liquid that surrounds the grains is called the continuous phase or dispersion medium. The emulsion contained in crude oil or crude oil can be stabilized by natural chemical substances contained in oil such as asphaltene, resin, and wax which are commonly known as natural surfactants (Umar et al., 2018; Yonguep et al., 2022). Emulsions present in crude oil are undesirable because water droplets and salts trapped in crude oil can cause production problems such as corrosion of pipelines and petroleum refinery equipment. Given this problem, the water contained in crude oil must be separated (Onojake & Waka, 2021; Sari & Sauqi, 2020).

Meanwhile, there is demulsification process, which is to separate the emulsion into constituent phases which means breaking the crude oil emulsion into an oil phase and a water phase (Zolfaghari et al., 2016). There are two aspects in demulsification, namely the speed of emulsion separation that occurs and the amount of water that leaves the crude oil after separation (Issaka et al., 2015; Sousa et al., 2022). In the petroleum industry, the presence of an emulsion will cause many losses (Abdulredha et al., 2020). The more asphaltene contained will increase the concentration of water contained in crude oil, increase the viscosity of crude oil, reduce the quality of petroleum, and disrupt the production process (Farooq et al., 2021; Struchkov et al., 2020). This demulsification process aims to break the emulsion in crude oil therefore the water and oil phases are separated (Alao et al., 2021; Raya et al., 2020).

The main source of basic fabric of disposable diapers consists of an absorbent pad sandwiched between two layers of non-woven fabric that guides moisture toward the hydrophilic core of the diaper while keeping the baby's skin comfortable (Bachra et al., 2020). Once moisture reaches the core, it comes into contact with sodium polyacrylate powder, a semi-crystalline super absorbent polymer (SAP). SAP or hydrogel is a loosely bonded three-dimensional network of flexible polymer chains that carry dissociated ionic functional groups (Kiatkamjornwong, 2007; Zhang et al., 2021). These are basic materials that can absorb fluids over 100 times their dry weight, either under load or without load, such as water, electrolyte solutions, synthetic urine, salt water, and biological fluids such as urine, sweat, and blood. They are polymers characterized by hydrophilicity containing carboxylic acids, carboxamides, hydroxyl, amines, imide groups, and so on, are insoluble in water, and are cross-linked polyelectrolytes. Due to their ionic nature and related structure, they absorb large quantities of water and other aqueous solutions (Ekebafe et al., 2013; Khoerunnisa et al., 2021).

2.Method

The research was carried out experimentally using materials such as oil samples of the light oil type, sodium chloride solution, and SAP. In this study, the authors made a comparison in separating oil-in-water emulsions using SAP and without using SAP, therefore it can be seen whether the separation is more effective using SAP or without using SAP.

In the research that was conducted for two months, an experiment was carried out using waste-based ingredients, namely used diapers which later the inside of the pampers or also known as SAP will be put into a test tube which will be mixed with oil sample that has been heated and then rotated using a centrifuge machine with a predetermined time. A detailed research flowchart illustrating the experimental procedure was provided for clarity on Figure 1.

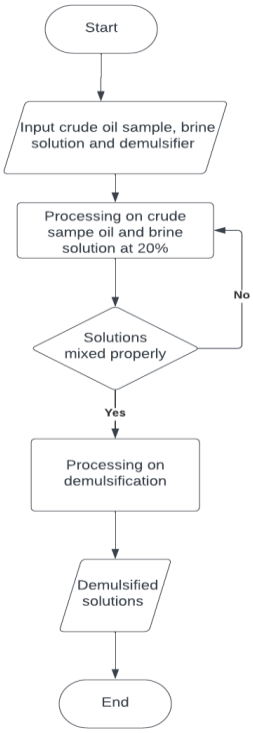

Figure 1 Flow chart

Table 2 shows the tools and materials that were used for this research.

Table 2
Tools and materials

Tools	Materials
Heater	Crude oil sample P441
Stirrer	Brine solution
Beaker 250 ml	SAP from waste diaper
Scale	Demineralize water
Spatula	Acid-base buffers
Cup	Alcohol
Densitometer	
Syringe	
Beaker 50 ml	
Beaker 1000 ml	
Viscometer	
Rotor	
pH meter	
Beaker 100 ml	
Centrifuge	
Test tube	

2.1. Crude Oil Sample and Brine Solution Preparation

The crude oil sample used in this study came from a temporary processing tank available in the laboratory. The physical property of this crude oil was light oil. Work procedures that implemented in making this solution include: a) Prepare 100 ml of demineralized water, b) Prepare 20 grams of sodium chloride for a 20% salinity concentration and 70 grams for a 70% salinity concentration, c) Prepare the heater and stirrer, d) Dissolve sodium chloride with distilled water in a beaker that has been placed with a stirrer that functions as a stirrer, e) Stir the solution within 10 minutes at high temperature, until the solution becomes homogeneous. The effect of temperature on the demulsification process is carried out by varying the heating temperature. Crude oil samples were heated at 40^0C and 50^0C.

2.2. Crude Oil Physical Characteristic

In this study, to determine the density and specific gravity of the crude oil sample, a densitometer was used. The work procedures that have been carried out in determining the density and SG are: a) Turn on the densitometer by pressing the 'ON' button on the back of the tool, b) Calibrate the tool by injecting demineralized water into the tool so that the density reading on the sample is optimal, c) Inject the sample into the densitometer, then wait for the reading. densitometer from the remains of crude oil using alcohol by injection. In addition, the Figure 2 is the densitometer:

After measuring with densitometer, a tool called a viscometer (Fig. 3) has been used to obtain the viscosity value of the crude oil sample. The work procedures that have been carried out in determining the viscosity are: a) Turn on the viscometer tool by pressing the 'ON' button, b) Install and select the rotor (1,2, and 3) on the viscometer tool, c) dipping the rotor into a beaker containing crude oil samples, d) Setting the menu on what type of rotor viscometer we use, e) If everything has been set, press 'OK', then do it three times, and average the readings.

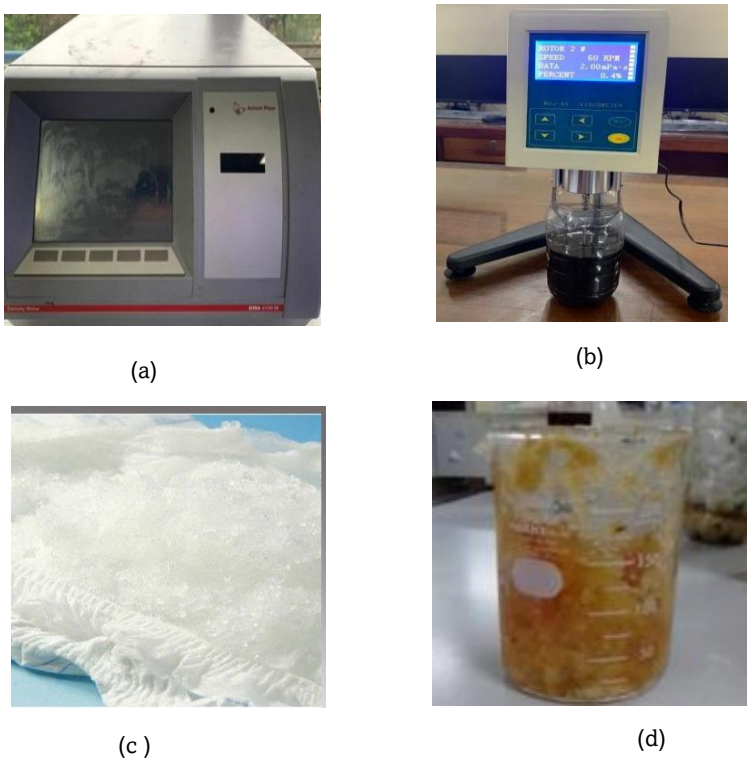

Figure 2. (a) Densitometer, (b). Viscometer, c. Super absorbent polymer. d. The waste of super absorbent polymer from used diaper

On top of that, after viscometer, a tool called a pH meter was used to obtain the pH value in crude oil samples. The work procedures that have been carried out in determining the pH are: a) Turn on the pH meter, b) Calibrate the pH meter with a basic or acidic buffer solution, c) Dip the pH meter into a beaker that has been filled with crude oil samples, and observe the readings of the pH meter, d) When finished, clean the pH meter using demineralized water.

2.3. Demulsification

The demulsification test in this study was carried out using a centrifuge, which aims to compare the crude oil separation test using a demulsifier that made from used pampers, namely SAP, which is an absorbent substance contained in the used diaper, and without using a diaper. This comparison allowed for a comprehensive evaluation of the effectiveness of SAP in demulsifying crude oil-water emulsions. The following figure shown the SAP from diaper. In addition, the following figure is the waste of SAP that have been used, as shown on Figure 5. If there is contact with liquid, the SAP swells tremendously. Factors that supply absorbency to polymers are osmotic pressure, based on mobile counterions, and the affinity between the polymer electrolyte and water (Venkatachalam & Kaliappa, 2023). The factor that suppresses absorption, on the other hand, lies in the elasticity of the gel resulting from its network structure. Not have a high liquid absorption capacity, but the absorbed liquid is difficult to release because it only immobilizes the liquid with an entrapment rather than by retaining it within the structure.

The SAP commonly found in diapers can also be called sodium polyacrylate which is capable of absorbing large amounts of water because the sodium ions attached to it attract water. SAP includes several polymers all of which have the basic ability to absorb large amounts of water (Kang et al., 2017). They absorb water using the process of osmosis (water molecules pass through the barrier from one side to the other), whereby when water comes into contact with the polymer, it moves from the outside of the polymer inwards and causes it to swell. Polymer chains have elastic qualities, but they can only stretch so far and hold so much water. Four SAPs are commonly used including sodium polyacrylate, polyacrylamide crystals, polyacrylamide plant spikes, and Gro-Creatures (Moayyad Al-Nasra & Batoul Alshamali, 2022).

Every polymer has a function of effectiveness in absorbing water, it's just that it has a slightly different mechanism for achieving its absorption value. The polymer has non-toxic hydrophilic properties, which can absorb several hundred times its weight in water but is insoluble due to its three-dimensional polymer network structure (Guan et al., 2019). They are attractive and highly versatile materials because of their unique solubility and transport properties. The fluid-like properties result from the fact that the polymer consists almost entirely of water. However, polymers also exhibit solid-like properties due to the networks formed by the reactions. Composed of potassium, carbon, and nitrogen. Conversely, it is commonly found is in disposable diapers Sodium Polyacrylate or Super Slurper Sodium polyacrylate is nicknamed "super slurper" because of its ability to absorb hundreds of times its mass in water. These polymers were originally developed by the Department of Agriculture, but much more absorbent synthetic polymers have recently been developed (Arpit & Jaya, 2023).

The work procedures that have been carried out in this demulsification method are: a) Prepare 4 test tubes, put 10 ml of crude oil and salinity solution into the test tube with a ratio of 1:1. For the experiment using SAP crude oil, salinity solution and used SAP as much as 5 ml, 4 ml, and 1 ml respectively, b) Shake the solution first before putting it into the centrifuge so that all the solutions are mixed, c) Put the 4 test tubes into the centrifuge with total time 3 minutes and set at 500 RPM. Then every minute the sample is observed and the difference is recorded, d) The same thing is done at a speed of 1000 and 1500 RPM with a time of 3 minutes each.

3. Result and Discussion

The following are the results of measuring the characteristics of the P#441 crude oil sample, which can be seen in the table below.

Table 3
The characteristic of crude oil sample P441

Parameter	Crude Oil Sample P441
Density	0.82 gr/cm3
Specific Gravity	0.82 (dimensionless)
The American Petroleum Insitute gravity (API gravity)	38.31^0API
Viscosity	2 cP

According to the fluid characteristics above; it shows that the type of crude oil sample that the author used was light oil. In this study, a low concentration of salinity was used in the emulsifying process for the P441 sample. This was also carried out to determine the optimal conditions for water separation in the demulsification process and to determine the effect of salinity on the mechanism of emulsion destabilization. The purpose of using salinity water is as a substitute for formation water which is usually mixed in crude oil.

In this study, testing was carried out at room temperature 260C and 400C, to see whether the separation using a room temperature of 260C or with an addition of temperature at 400C affects the separation process between water and crude oil. The effect of temperature can accelerate the separation of the emulsion. The volume of oil produced at 400C is less than the volume of oil produced at 260C, this is because the temperature can reduce the viscosity value of crude oil, thus making crude oil more liquid. In this experiment, the condition of the two test tubes which contained waste and which did not contain waste before being put into the centrifuge machine for further comparisons was carried out. The separation with a different rotating radius speed is 1500 RPM. Furthermore, after being inserted into the centrifuge machine in the first minute with a rotating radius speed of 1500 RPM. It can be seen that there is a significant separation between water and crude oil, more likely a tube without waste, there is still oil involved in the water so the resulting water volume is 4.6 ml. In contrast to the tube containing waste, it gets a water volume value of 5 ml because water has been absorbed into the SAP. This situation continued until the third minute and two tubes are constant average with the same volume of water. The figure below shown as the result of the separation between crude oil and water, as well as the best result, it was determined that the mixture with SAP waste at 40^0C and 1500 RPM.

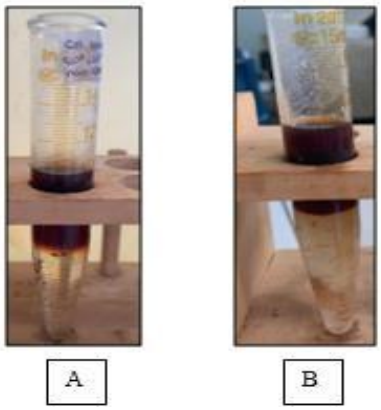

Fig. 3 (a)Demulsification without SAP waste (b)Demulsification with SAP waste

Based on Figure 6, there is a difference between the P#441 crude oil samples that were given SAP demulsifiers and those that were not given. In picture 'a' it can be seen that the crude oil and the salinity solution blend after being shaken before being put into the centrifuge, but this is different from picture 'b', it can be seen that there is already a difference in density when the waste material is added. In the experiment in picture 'a' the 1:1 method is used, namely 5 ml crude oil and 5 ml salinity to test whether the separation is effective or not without using waste, and in picture 'b' the 1:1 method is also used, but there are differences in the parts that are used. 4 ml of water and 1 ml of Superabsorbent were injected. This is because most of the waste demulsifier already contains water. The result of demulsification for the best result at 400C and 1500 RPM also can be seen in the table below, as follow:

Table 4
Result of demulsification

Material	Water volume with SAP waste (ml)	Water volume without SAP waste (ml)	Time (minute)
Crude oil P441 with 20% salinity	1	0	0
	5	4.6	1
	5	4.8	2
	5	5	3

As the result of Table 4, the amount of water volume initially increased for the experiment using SAP waste, it shown that at the initial period, the water volume had increased from 1 ml to 5 mL. It indicates that the demulsification was run well with the experiment using SAP waste. Also, with the increased RPM number and temperature, it turned out that it affected the speed of oil and water in separating, and for maximum results, the use of this SAP material had worked well.

4. Conclusion

After conducting research on the separation of crude oil and water using the main source of diapers waste, several conclusions can be drawn as follows: a) At 400°C the demulsification process occurs faster than at 260°C, due to a decrease in the viscosity level, b) Calculation of the average which is obtained in the volume of water with SAP waste at 260°C of 3.7 ml, then in the volume of water without waste at 260°C of 3.4 ml. Furthermore, the volume of water with SAP containing waste at 400C is 3.98 ml, and finally, the volume of water with SAP without waste at 400C is 3.58 ml. Therefore, it can be concluded that using SAP and a temperature of 400°C can produce a more efficient volume of water, c) Because SAP is hydrophilic and can bind water in the silica gel network so that water will be trapped, d) In research conducted by the author regarding the separation of salinity solutions with crude oil that using SAP material tends to be more effectively separated compared to not using SAP.

Acknowledgments

The acknowledgement is dedicated to the Dean of Faculty of Earth Technology and Energy, Universitas Trisakti, the Head and Secretary of Petroleum Engineering, Faculty of Earth Technology and Energy Universitas Trisakti, and the team of Enhanced Oil Recovery Laboratory, Petroleum Engineering Department, Faculty of Earth Technology and Energy Universitas Trisakti for the supports on this research.

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