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The Investigation of Paraffin Handling with Parasol and Xylene Chemical Treatment: A Case Study in Sangasanga Field, Indonesia

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Abstract: Paraffin deposition is a problem in producing hydrocarbons that can result in losses. Paraffin can form near a wellbore, tubing, or other production facilities. Temperature differences are one of the causes of paraffin depositions. When the temperature of a fluid starts to fall below its pour point, oil flows more slowly. The temperature at which paraffin begins to form is known as the "wax appearance temperature." The development of paraffin can reduce production rates, damage production equipment, and lead to economic losses. In many cases, paraffin can also develop near the wellbore, which can cause formation damage. As a result, when paraffin begins to form, the problem must be handled as soon as possible to minimize more severe damage. The chemical method has been proven to be effective in dealing with paraffin problems. A solvent dissolves the paraffin and reduces the oil's viscosity, allowing it to flow more easily. This study aims to discuss laboratory studies of two different solvents and analyze the best scenarios that can be applied in the field to overcome paraffin problems in the Sangasanga Field and its effect on permeability improvement. The method used in this study is laboratory testing of fluid properties, solubility tests, and permeability tests. This study shows that the Parasol solvent can dissolve paraffin up to 98.2% and improve permeability up to 94.9%.

Keywords: Paraffin Deposition, Formation Damage, Chemical Method, Solvent, Permeability Improvement

1. Introduction

In producing oil, it constantly strives for optimum production. When there is a drastic decrease in production capacity and oil production rate from a well, evaluation and identification must be made as soon as possible to deal with the problem. One cause of the decline in production can be the deposition or development of paraffin, which disrupts fluid flow in the wellbore, pipelines, and production equipment.

Wax deposition may result in production loss, mechanical failure of tubular equipment, increased production downtime, and decreased profitability [1]. The primary causes of wax deposition are environmental changes, such as temperature, pressure, and the loss of dissolved gases, which impact solution equilibrium. Wax deposition can also cause formation damage at the wellbore, such as physical blockage or permeability impairment, wettability alteration, fluid composition changes, and fluid rheology changes as solid wax precipitates due to phase separation [2, 3]. Paraffin remediation can be challenging when deposition occurs in the formation, especially near producing wells. There are several methods for handling paraffin, one of which is the chemical method [4, 5, 6]. Numerous studies have shown that chemical injection with soaking time can overcome paraffin problems and increase production in wells with paraffin problems, especially in the wellbore [7, 8].

However, before proceeding to the field implementation, laboratory studies are required to analyze crude oil samples, chemical effectiveness, and the effect of chemicals on permeability. This paper discusses the performance of two different chemical applications at the lab scale that will be used to handle downhole wax deposition in the Sangasanga oil field's wells, using Parasol and Xylene. Both chemicals are solvents that will dissolve the wax [9]. In addition, we performed a permeability test as an innovation to determine the permeability changes to the treated core.

The authors hope that this study will serve as a reference and guidelines for handling paraffin problem that occurs in Indonesian oil wells in order to improve oil production.

2. Literature Review

2.1. Paraffin Deposition

Crude oils are complex mixtures of paraffin (linear and iso-alkanes) concentrated in the lower boiling fractions, naphthene (cyclo-alkanes), aromatics (mono- and poly-nuclear, mono- and poly-alkyl substituted or unsubstituted), heteroaromatics (containing sulphur, nitrogen, and oxygen heterocycles), resins, and even traces of the composition varies greatly depending on the crude source. It determines light, medium, and heavy crudes. Linear paraffin is also known as wax, while Asphaltenes are complex poly-heteroaromatic compounds with long alkyl chains and metal chelates like vanadium or nickel [10]. Wax can be dissolved in oil in a fluid phase and may become insoluble under particular conditions. The decrease in temperature is one factor that leads to the formation of crystals in the wax. The wax will remain soluble in the reservoir and experience thermodynamic equilibrium with crude oil. Components over C20 provide enough solidifying material for paraffin at low temperatures, whether their structures are linear or saturated with carbon bonds. Higher temperatures make these components unstable in liquid mixtures [11].

2.2. Factors Affecting Wax Deposition

According to Gudmundsson & Bott, 1977, three factors influence wax deposition in the flow system, including flow rate, temperature difference, distribution, and chemical nature.

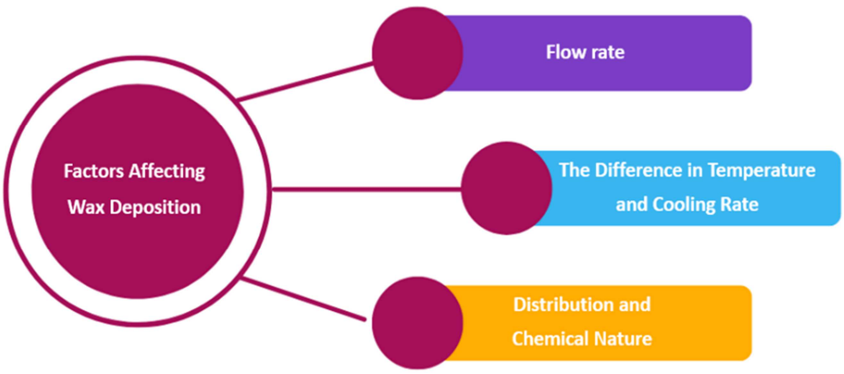

Figure 1. *Factors Affecting Wax Deposition.*

2.2.1. Flow Rate

In laminar flow, the deposition will increase as the flow rate increases. The higher flow rate in laminar flow carried more particles, causing more deposition on the pipe surface. Shear dispersion is the main element in a turbulent flow. Due to shear dispersion, deposition decreases as the flow rate increases to turbulent flow [12]. In contrast, the flow behavior in a flowing system is expressed in Reynolds number.

2.2.2. The Difference in Temperature and Cooling Rate

The temperature difference is a factor that affects the deposition of wax. As the temperature increases, the solubility of the wax also increases. Wax will increase with increasing the temperature difference. Wax will form when the surface temperature is below the oil temperature and the oil cloud point temperature. The wax appearance temperature is the first temperature when waxing forms (WAT) [13, 14]. The size and number of crystals created in the wax deposition are also crucial factors. Wax precipitates out as smaller crystals at a higher cooling rate, and many crystals form due to a large number of crystallization sites. Slower cooling produces uniform crystallization and crystals with a smaller surface area and free energy [6].

2.2.3. Distribution and Chemical Nature

The chemical properties of the wax and solution can impact the deposition process by altering the adsorption forces that hold deposits in place. The structure of wax crystals will also be necessary, depending on the chemical composition and rate of production. Because of these and other factors, the structure of the resulting layer in any deposition process is unlikely to be uniform, allowing planes of weakness to form, and giving rise to a random process of wax layer growth and removal [12].

2.3. Paraffin Removal with Solvent

Chemical wax control methods have been widely used to prevent and solve wax deposition problems. Three chemicals remove paraffin deposits: solvents, dispersants, and surfactants. Solvents act to dissolve paraffin deposits. Care must be taken when using a chemical solvent in its selection and use. The universal solvents commonly used are carbon tetrachloride and carbon disulfide. Meanwhile, Kerosene, condensate, and diesel oil remove the low asphaltene content paraffin deposits [5]. Chemical solvents are utilized when crude oils are sensitive to surfactants and create emulsions or generate water with dissolved solids. They dissolve a particular amount of wax based on MW, pressure, and temperature [15, 16]. Chemical solvents have the benefit of being economical and not requiring complex equipment. However, this technique may be less effective for dissolving more significant amounts of wax [17].

Figure 2. *Samples of Paraffin in Sangasanga Field.*

3. Case Study

Sangasanga Field is a field located in the Kutai Basin. In producing oil, Sangasanga Field experiences several production problems that occur according to the reservoir and the crude oil characteristics, including sand problems, high pour point oil, gas inferences, scale, and other facility problems. One problem that occurs and hinders the production process is the paraffinic problem. The current paraffinic problems mainly affect producing wells in the D & E layers of the North Kutai Lama formation. This problem has a significant impact on the production performance of this structure, which in turn impacts the overall production performance of the Sangasanga field.

One of the wells studied is ACZ-07 Well, where paraffin deposition occurred in the near-wellbore of well ACZ-07, resulting in plugging in the perforation and hindering production flow from the reservoir to the well, which resulted in a small production potential of 20–30 BOPD and a short lifetime due to the discontinuous production flow caused by paraffinic deposition. The well has been shut since June 2020, with a last production of 5 BOPD. Well-tested data and a low IPR support this. According to reserve calculations, 25 MSTB of oil can still be produced. Because the well has a lot of production potential, it is crucial to figure out how to deal with the paraffinic issues in the ACZ-07 well.

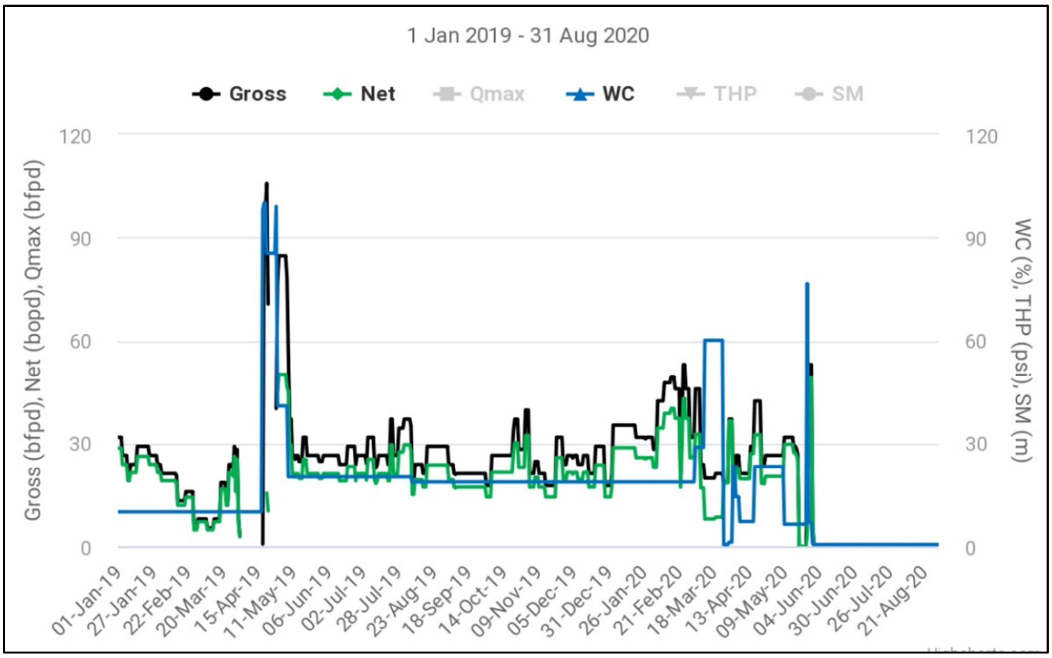

Figure 3. *Production Well Performance ACZ-07 Well.*

4. Methods

The laboratory tests have been performed to observe the properties of crude oil samples, chemical solubility, and chemical ability to overcome paraffinic problems with the sensitivity of the type of chemicals, concentrations, and duration time. The output of this stage is to select the best chemical properties for the stimulation.

4.1. Specific Gravity and API Test

Testing crude oil properties were conducted to determine the characteristics of the production fluid in well ACZ-07. This test included API, viscosity, and pour point measurements. The API was measured using the ASTMD-1298 method utilizing a hydrometer and thermometer. The sample is heated to the reservoir temperature of 70°C. The temperature is recorded with the thermometer, specific gravity is recorded with the hydrometer, and the actual API value is then calculated.

Figure 4. *Specific Gravity Testing with a Hydrometer.*

4.2. Viscosity Measurement

On the viscosity test, a Brookfield viscosity meter was utilized. The principle of this equipment is to measure fluid resistance at various shear rates depending on torque. The sample is heated to 70 °C. The substance is then moved to a 10-mL measuring cup and tube. The torque is then adjusted according to the tool's handbook to 20 revolutions per minute. The viscosity was measured for approximately 10 minutes until the instrument showed a steady result.

Figure 5. *Viscosity Measurement with Brookfield Viscosity Meter.*

4.3. Pour Point Measurement

Pour point testing uses a thermometer and a water bath to condition the sample. The heated sample is then placed in a tube that has been closed and fitted with a thermometer. In addition, the sample is placed in a bath containing ice cubes. The sample is left to stand and is monitored until it reaches the temperature at which the oil cannot flow. The temperature is then recorded as the pour point temperature.

Figure 6. *Pour Point Measurement with Water Bath and Thermometer.*

4.4. Solubility Test

Solubility tests were performed to select the optimal chemical properties for dissolving paraffin. This test was carried out by chemical type sensitivity (Parasol and Xylene), chemical concentration (paraffin wax: volume chemical; 1: ¼, 1: ½, 1:1), and immersion time (60 minutes, 120 minutes). The testing is conducted by weighing 2 grams of paraffin sample. The sample is soaked with chemicals and shaken for around 60 seconds to ensure the chemicals come into contact with the oil. After immersion, the sample is sorted into dissolved and insoluble components with filter papers. The non-dissolved part is then vacuumed and left for 24 hours. The dried sample of paraffinic oil results are then weighted, and calculate the solubility with the equation:

$$\%dissolve\ wax = \frac{inital\ mass - final\ mass}{initial\ mass} \tag{1}$$

Figure 7. *Solubility Test Procedure.*

4.5. Permeability Test

A permeability test was carried out to determine the effect of changes in permeability caused by chemicals. The chemical used is a chemical with the type, concentration, and duration which produces optimal results from the solubility test. The instrument utilized is a gas permeability test that calculates the gas transmission rate by detecting pressure changes in a low-pressure chamber and calculating the gas permeability. In this experiment, cores of varying permeabilities are used to determine the chemical effect of each core. The sample cores and their properties are shown in Table 1. The steps of testing performed are:

After calculating the porosity, permeability, and pore volume of the core, it is saturated with oil using a vacuum desiccator. The sample's permeability is next measured, and the result is recorded as either result (1) or permeability after saturation.

The sample was then left for two days, its permeability was recalculated, and the results were recorded as result (2) or D+2 after saturation.

The core sample is then treated with a chemical at a volume ratio of 1:1, or 100% (pore volume: chemical volume), for two hours. Then, the core left for two days, and the core returned for measurement and was recorded as result (3), or D+2 after treatment.

Table 1. *Core Samples Initial Permeability.*

Sample Core	Permeability (mD)
Tan 2	357.18
4	213.93
2	18.52

(a) (b)

Figure 8. *Permeability Testing Procedure with (a) a Vacuum Desiccator and (b) Gas Permeameter.*

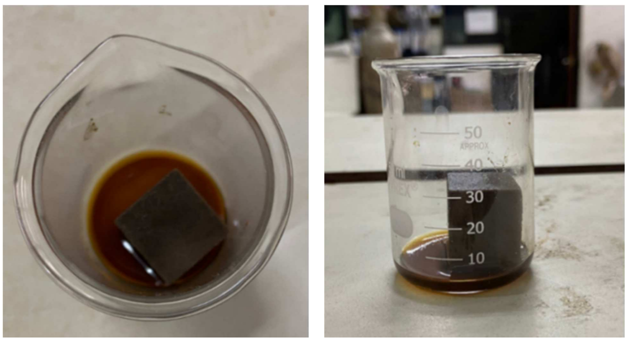

Figure 9. *Process of Immersing Core Samples in Parasol.*

5. Results and Discussion

5.1. Crude Oil Properties

Table 2 shows the fluid properties of the ACZ-07 well based on the tests conducted. The SG and API values indicate that the sample is a medium oil with a relatively low viscosity value. Before performing the crude oil properties test, the crude oil is heated to 70 °C to simulate reservoir conditions. The pour point indicates that the oil begins to have difficulty flowing at 34°C. According to the results of the oil pour point test, the presence of paraffin problems in the near-wellbore area at temperatures that are still relatively high indicates plugging caused by long-term paraffin accumulation, which causes a blockage to the flow of oil from the reservoir into the well, so it is reducing the well's flow rate, productivity index, and IPR.

Table 2. *ACZ-07 Well Oil Properties (T=70°C).*

Specific Gravity	°API	Viscosity, Cp	Pour Point, °C
0.88	29.37	3.1	34

5.2. Solubility Test

In the analysis of paraffin handling using the chemical solvent method, the authors summarized various studies with methods that are almost identical to the authors' research: King, Francis-Lacroix, & Orosco, 2021 [18], validating the performance of paraffin solvents by conducting a solvation test and comparing the performance of three types of chemicals to select the solvent with the best performance in dissolving, break-up, and removing the paraffin deposits. Maulirany, Bahruddin, & Yelmida, 2013 [19], performed a solubility test with the addition of a temperature variable to examine the effect of temperature on solubility. Nahampun, 2022 [20], conducted a solubility test in her research to measure a solution's ability to dissolve in a solvent.

In this study, solubility testing is conducted to determine the effectiveness of a chemical in dissolving paraffin. The solvents utilized in this test are Parasol and Xylene, which are known to be designed to overcome paraffin problems in wellbore, formation, and surface/downhole production equipment. In this test, the ability of the Parasol and Xylene solvents will be compared to overcoming the paraffin problems in the Sangasanga field. Tables 3 and 4 show the physical and chemical specifications for each chemical**.**

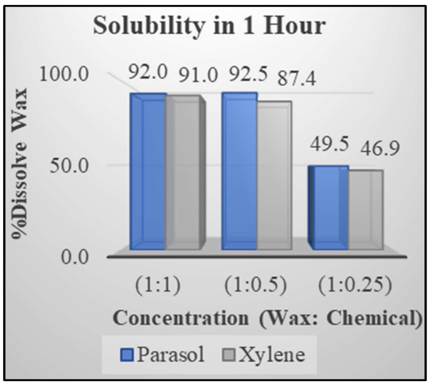

Figure 10. *Solubility Test Results for 1 Hour.*

Table 3. *Specification of Parasol.*

Parameter	Specification	Analysis
Physical properties	Liquid	Liquid
Color	No color	No color
Specific gravity	0,8-0,95	0,87
Solubility in water	Insoluble	Insoluble
Solubility in hydrocarbon	Soluble	Soluble

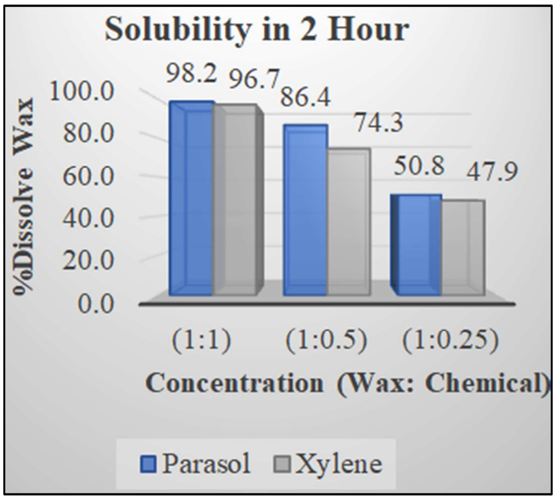

Figure 11. *Solubility Test Results for 2 Hour.*

Table 4. *Specification of Xylene.*

Parameter	Specification	Analysis
Physical properties	Liquid	Liquid
Color	No color	No color
Specific gravity	0,87-0,01	0,86
Cinematic Viscosity (Cp)	0,7-0,001	0,69
Flash Point (°C)	Min 23	25
Solubility in water	Insoluble	Insoluble
Solubility in hydrocarbon	Soluble	Soluble

Figures 10 and 11 shows a comparison of the results of the solubility test using Parasol and Xylene for each volume ratio and immersion time. The results showed that the Parasol, with a concentration of 1:1 (wax: chemical) and an immersion duration of 120 min, had the highest solubility of 98.2%. Figure 12 shows the number of residual paraffin samples after chemical immersion, where the end test indicates that just 0.037 grams of the initial 2.049 grams sample are insoluble.

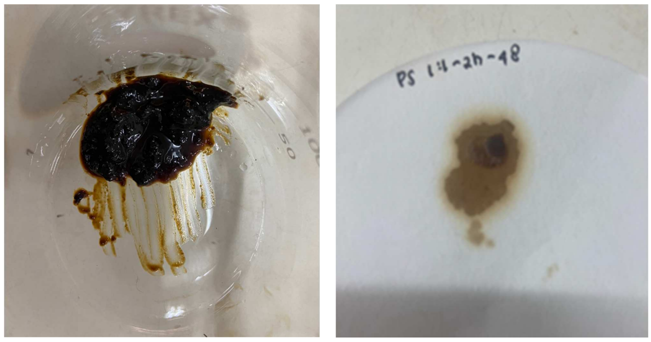

Figure 12. *Crude Oil Samples After Being Treated with Parasol.*

5.3. Permeability Test

In this paper, permeability testing is a novelty test that has not been previously investigated. Permeability testing was carried out to evaluate changes in core permeability after treatment and to determine the solvent's ability to dissolve paraffin, which blocks the rock pores. Furthermore, this test can also confirm the success of stimulation on a field scale.

The following is a comparison table of tests performed on paraffin investigation using chemical methods in several studies:

Table 5. *Laboratory Analyses of Paraffin in Several Studies.*

Study	Laboratory Testing Performed
Angelica, et al, 2023	Crude Oil Properties Test, Solubility Test, and Permeability Test
King, Francis-Lacroix, & Orosco, 2021 [18]	Paraffin Inhibitor Testing and Validation using a Multi-Cold Finger (MCF) Apparatus and Paraffin Solvent Testing and Validation using a Solvation Test or Pumper's Test
Maulirany, Bahruddin, & Yelmida, 2013 [19]	Solubility test, Gas Chromatography Analysis, and SARA Analysis (Saturated, Aromatic, Resin, and Asphaltene)
Nahampun, 2022 [20]	Compatibility test, Solubility test, and Viscosity Test

To perform permeability testing, first, core samples are saturated with oil samples in the Sangasanga field. Table 6 displays the results of the permeability test utilizing gas permeability in various conditions.

Condition (1) shows permeability results in core samples that have been saturated with oil. The oil is still above its pour point in this condition. This is confirmed by the presence of residual oil that can still flow and come out of the core after the test.

Condition (2) shows the permeability test results on the core sample after two days. In this condition, the oil in the core is below its pour point or solidifies. This condition simulates a decrease in permeability caused by the plugging of paraffin accumulation.

Then, condition (3) shows the results of treated core permeability after two days. According to the results of the tests, using a parasol solvent with a wax: chemical ratio of 1:1 and a soaking time of 2 hours improved the permeability of the core.

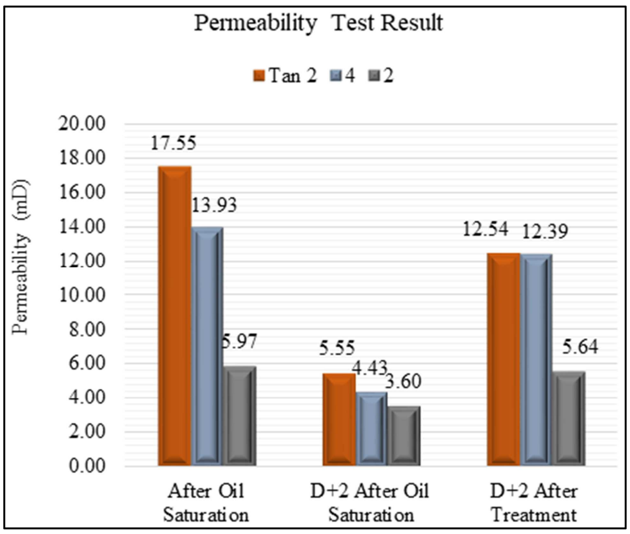

Figure 13. *Value of Permeability for Each Test Condition.*

***Table 6.** Tabulation of Permeability Test Results.*

Permeability	Sample Core		
	Tan 2	4	2
(1) After oil saturation (mD)	17.55	13.93	5.97
(2) D+2 after oil saturation (mD)	5.55	4.43	3.60
(3) D+2 after treatment (mD)	12.54	12.39	5.64

According to the permeability test results, there was an improvement in permeability after the core was treated with chemicals. The increase in permeability improvement can be determined by comparing the core's permeability after oil saturation to its final permeability after treatment (D+2 after treatment). Based on calculations, the permeability improvement for sample Tan 2 core is 71.5%, sample 4 is 88.9%, and sample 2 is 94.9%. Significant improvement in permeability proves that the Parasol chemical utilized effectively overcame paraffin problems in the near-wellbore of ACZ-07 well in the Sangasanga field. Paraffin accumulation in the wellbore, which solidifies and reduces permeability, makes it difficult for oil to flow. The chemical will dissolve the paraffin that has accumulated, hence improving permeability. An increase in the formation's permeability will improve the value of the productivity index and production rate, thus further improving the well's production performance.

6. Conclusions

Following are the conclusions that may be drawn from the studies that have been conducted:

Paraffin accumulation that occurred near the wellbore in the ACZ-07 well in the Sangasanga field caused plugging and flow blockage in the perforation area, which resulted in a decrease in the production rate, productivity index, and well IPR.

Based on the solubility test results, the chemical parasol has a higher solubility value for dissolving wax up to 98.2% at a concentration of 1:1 and a soaking time of 2 hours. As a result, this study confirms that Parasol is more effective in overcoming paraffin issues in the ACZ-07 well.

The effectiveness of chemical performance is also confirmed based on the permeability test results. There was an improvement in permeability up to 94.9% after the core was treated.

A significant change in permeability causes an increase in production rate, productivity index, and production performance improvements in wells, as well as an increase in the production life of well ACZ-07.

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