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Analysis Of Density, Turbidity, And Chloride Content In Potassium Chloride Samples For Drilling Processes

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Abstract

Petroleum remains a key energy source in Indonesia, driving continuous drilling to find new oil reserves. Drilling operations rely on potassium chloride (KCl) as a supporting chemical, functioning to stabilize rock formations, reduce pipe corrosion, and control wellbore failure. KCl used for drilling must meet quality standards set by Scomi Oiltools' Drilling Fluid Engineering handbook. This Field Work Practice, conducted at LEMIGAS, Jakarta, evaluated the density, turbidity, and chloride content of eleven KCl samples from three companies against Scomi Oiltools standards. Density was measured using an Automatic Density Analyzer (ASTM C604); turbidity via Direct Reading Spectrophotometer (ASTM D7315-17); and chloride content through Mohr argentometric titration (ASTM D512-04; SNI 6989.19:2009). Results showed densities of 1.9–2.9 g/mL, exceeding the ideal 1.0–1.16 g/mL range, and chloride levels of 1,950–2,060 ppm, far below the required minimum of 4,700 ppm. Turbidity ranged from 1–80 FTU, with all but one sample meeting the standard below 20 FTU. Thus, while turbidity generally complied, density and chloride content of all samples failed to meet Scomi Oiltools standards, highlighting the need for rigorous quality testing before selecting KCl for drilling use.

Keywords: Argentometric Titration, Density Analysis, Drilling Fluid, Potassium Chloride

Introduction

Petroleum remains one of the most essential energy sources for the Indonesian people. One of the main factors driving the high demand for petroleum in Indonesia is the population's high level of

mobility. As an archipelago with a large population spread across numerous islands, nearly all Indonesians rely on petroleum as an energy source for transportation whether by land, sea, or air. Motorized vehicles, including both two-wheeled and four-wheeled vehicles, remain the primary means of transportation for Indonesians in their daily activities (Sa'adah, 2017)

The Indonesian government particularly the Ministry of Energy and Mineral Resources and other agencies involved in the oil and gas sector continues to strive to meet the public's demand for petroleum products. Various efforts have been undertaken to optimize the potential of existing local oil resources, such as the search for new oil reserves and innovations in renewable production technologies. The map of oil and natural gas reserves in Indonesia maintained by the Ministry of Energy and Mineral Resources indicates that Indonesia's oil reserves are projected to last for the next 9.5 years, while the natural gas reserves are projected to last for 19.9 years. This assumption is based on the premise that there are no new discoveries and that current production levels remain at 700,000 barrels of oil per day (BOPD) and 6 billion standard cubic feet of gas per day (BSCFD). These oil and gas reserve calculations are based on 2020 reserve data and assume no new oil and gas discoveries (Arief et al., 2021). In 2023, PT Pertamina Hulu Energi discovered new oil reserves: the East Akasia Cinta (EAC)-001 well in the PEP Jatibarang Field operational area, Indramayu Regency, and the East Pondok Aren (EPN)-001 well in the PEP Tambun Field operational area, Bekasi Regency. The search for other oil reserves continues to this day.

Table 1. The quality characteristics KCl based on Scomi Oiltools

Weight (%)	Density (kg/l)	Cl ⁻ (mg/l)	K ⁺ (mg/l)
1	1,005	4756	5.244
2	1,011	9606	10.594
3	1,017	14504	15.996
4	1,024	19498	21.502
5	1,030	24491	27.009
6	1,037	29579	32.621
7	1,043	34715	38.285
8	1,050	39947	44.053
9	1,057	45225	49.875
10	1,063	50551	55.749
11	1,070	55973	61.727
12	1,077	61442	67.758
13	1,084	67006	73.894
14	1,091	72617	80.083
15	1,097	78276	86.324
16	1,104	84030	92.670
17	1,111	89832	99.068
18	1,119	95729	105.571
19	1,126	101721	112.179
20	1,133	107760	118.840
22	1,147	120030	132.370
24	1,162	132632	146.268

(Scomi, 2008)

One of the key processes in the discovery of new oil reserves is drilling. Drilling is crucial for discovering new oil reserves because it provides certainty as to whether a given area has the potential to become a new source of oil (Putra & Kiono, 2021). In practice, the drilling process requires various chemicals to help improve drilling efficiency. One such chemical is potassium chloride (KCl). According to (Shi et al., 2019), potassium chloride has various uses in drilling, such as: 1) stabilizing

rock formations during drilling, 2) reducing corrosion, and 3) preventing wellbore failures. Given its various benefits for drilling, KCl is an essential chemical in the drilling process. However, not just any KCl can be used as a drilling aid. KCl intended for use in the drilling process must meet the criteria outlined in the salt tables referenced in the book “Drilling Fluid Engineering” by Scomi Oiltools; therefore, testing of KCl quality and characteristics such as density, chloride content, and turbidity is required.

Drilling mud is a critical factor in the drilling process, as it affects drilling speed, safety, and costs. There are three types of drilling mud used in drilling operations: Water-Based Mud (WBM), Oil-Based Mud (OBM), and Synthetic Oil-Based Mud (S-OBM) (Miranti et al., 2014). To ensure the drilling mud possesses the desired properties for drilling operations, various additives are incorporated into the mixture (Mahto & Sharma, 2004). However, some of these additives contain heavy metals that can impact the environment. According to (Burden et al., 2013) to develop an environmentally friendly drilling fluid system with equivalent technical performance, one must consider the impact of each component, evaluate its usage, and assess the waste generated by the system.

One of the parameters that must be considered in drilling operations is the hole cleaning parameter, or the removal of drill cuttings. Hole cleaning refers to the ability of drilling mud to remove drill cuttings from the bottom of the wellbore to the surface, and this parameter is one of the key indicators of a drilling operation's success, as cuttings that are not removed will cause numerous problems during the drilling process, such as repeated regrinding, cuttings buildup on the bit (bit balling), and stuck pipe and can even lead to suboptimal bit hydraulics, which is one of the causes of a decrease in the rate of penetration. Therefore, factors that hinder drilling operations must be avoided or prevented as quickly as possible to ensure that drilling operations remain optimal and efficient (Kusuma, 2022). The consistent addition of KCl and NaCl additives is ideal when drilling mud is operating at high temperatures because the viscosity, yield point, plastic viscosity, gel strength, water loss, and mud cake properties remain within acceptable limits at 220 °F. Based on the data on the physical properties of the six mud compositions tested, the experimental mud composition whose physical properties meet the standard specifications for drilling mud in terms of its resistance to high temperatures is composition B1. Therefore, KCl is superior overall (Lail & Satiyawira, 2015).

Method

There are three methods used; the first is the chloride test. In the chloride content test, a precipitation titration commonly known as argentometric titration is performed. The term “argentometry” is derived from the Latin word “argentum,” meaning silver. Thus, argentometry is a method for determining the concentration of a substance in a solution through titration based on the formation of a precipitate with silver ions (Ag^+). Argentometry is a method for determining the concentration of halides and other compounds that form precipitates with silver nitrate (AgNO_3) under specific conditions. The principle of the argentometric method is the formation of a relatively insoluble compound or precipitate (Mardiyono, 2020). The basis of argentometric titration is a precipitation reaction in which the substance to be quantified is precipitated by a standard silver nitrate (AgNO_3) solution and a chromatic indicator. Such substances include halide salts (Cl, Br, I), cyanide, thiocyanate, and phosphate. The final step involves titrating with a standard AgNO_3 solution until the endpoint is reached, at which point the solution turns brick red (Retno & Putri, 2022)

Next, a density test was conducted as the second test. Density measurements are important for industry to determine the purity of the materials to be used. Density measurements of solid compounds can be performed using an Automatic Density Analyzer. The Automatic Density Analyzer (ADA) is a gas pycnometer that operates based on Archimedes' Law of Fluid Dynamics and Boyle's Law of Gas Expansion. The Automatic Density Analyzer uses an inert gas helium (He) which exerts pressure even into the smallest pores and eliminates the effects of surface chemistry. Helium is commonly used as a displacement gas due to its size and inert properties.

Next, the third test was a turbidity test. The Direct Reading Spectrophotometer is a microprocessor-controlled “single-beam” spectrophotometer. In operation, this instrument functions like a standard spectrophotometer. Spectrophotometric analysis is based on the absorption of light by compounds in a sample, whereby some light is absorbed and the rest is transmitted (Hach, 2007). The Direct Reading

Spectrophotometer has been calibrated for more than 120 different colorimetric measurements, making it suitable for a wide range of tests. This instrument can also be used to measure water turbidity, as turbidity reflects the optical properties of water, which are determined by the amount of light absorbed and transmitted by the substances present in the water (Harini, 2013). In this study, a direct-reading spectrophotometer was used to test the turbidity of the KCl test solution. The direct-reading spectrophotometer used was manufactured by Hach Company, specifically the DR/2000 model.

Materials

The materials used in this test were 11 samples of potassium chloride (KCl) from three different companies: PT. JM Mutu Utama, Anaya Global Indonesia, and PT. Timuraya Tunggal; 0.282 N silver nitrate (AgNO_3) solution and 5% potassium chromate (K_2CrO_4) indicator from Merck; and water (Aqua) as the solvent.

Instrumentation

The equipment used in this test included beakers, erlenmeyer flasks, volumetric flasks, round-bottom flasks, measuring pipettes, droppers, burettes, spatulas, stirring rods, analytical balance, magnetic stirrer, glass bottles, thermometer, Automatic Density Analyzer (ADA), and Direct Reading Spectrophotometer (DR/2000).

Procedure

Density (ASTM C604)

The first step in measuring the density of KCl using an Automatic Density Analyzer is to weigh the empty chamber on a high-precision analytical balance. Record the weight of the empty chamber, then fill the chamber with the test sample to 4/5 of its volume. Compact the test sample by tapping the bottom of the chamber. Next, weigh the chamber containing the sample, record its weight, and subtract the weight of the empty chamber to determine the mass of the sample to be tested. Place the chamber into the Automatic Density Analyzer, close it, enter the sample mass into the device, and start the measurement process. Allow the measurement process to run for three repetitions.

Turbidity (ASTM D7315-17)

The turbidity of the test sample's KCl solution was measured using a DR/2000 direct-reading spectrophotometer. The first step of the test involved preparing a 5% KCl solution. Next, an "auto-zero" procedure was performed on the spectrophotometer using a solvent compatible with the KCl solution as a blank. Afterward, the 5% KCl solution was added to the chamber up to the 25 mL mark, and the chamber was inserted into the instrument. Perform the FTU turbidity test. The test should be repeated three times to verify the accuracy of the data. If the values obtained from one test differ significantly from those of the next, you should repeat the solution preparation or clean the chamber again.

Chloride (Cl^-) Content (ASTM D512-04; SNI 6989.19:2009)

Testing for chloride content in KCl test samples begins with the preparation of a 0.05 N KCl solution for each test sample. A total of 0.4 grams of the KCl test sample is dissolved in water in a 100 mL volumetric flask. Then, 25 mL of the KCl solution is pipetted into an Erlenmeyer flask, 5 drops of potassium chromate (K_2CrO_4) indicator are added, and the mixture is titrated with 0.282 N silver nitrate (AgNO_3) solution. The titration is continued until a brick-red precipitate forms.

Result and Discussion

Results of the KCl Analysis

Based on the test results, the following data were obtained:

Table 2. Results of the KCl analysis of the test samples

KCl Brands	Density (g/mL)	Turbidity (FTU)	Cl ⁻ content (ppm)
KCl JM BC09004	2,8752	2	2019,4
KCl JM BC06037	2,5886	1	1979,4
KCL JM 2BB12021	1,9854	80	1999,4
KCl JM BC06039	1,9947	5	1979,4
KCl Anaya HL046	1,9946	2	2099,4
KCl Anaya HJ174	2,0043	8	1878,4
KCl Anaya HL213	1,9919	11	2079,4
KCl Anaya HJ169	2,4558	7	2059,4
KCl Anaya HG110	2,0044	6	1959,4
KCl Anaya HH133	1,9942	14	1959,4
KCl Timuraya Tunggal	2,0755	10	2039,4

Based on the test results in Table 2, the density of the test samples' KCl ranged from 1.8 to 2.9 g/mL; the chloride content ranged from 1,950 to 2,060 ppm; and turbidity levels varied from 1 FTU to 80 FTU.

Testing the Density of KCl Test Samples

The density of KCl has a significant impact on the drilling process. The density of KCl greatly influences the hydrostatic pressure of the mud column at each depth. Knowing the exact density allows for more effective planning and more efficient use of drilling mud. An inaccurately determined density can lead to errors in planning, which will affect the success of drilling operations. Therefore, testing the density of KCl is a crucial step in the drilling process to ensure the success of operations and reduce unnecessary costs (Satyawira, 2018).

An Automatic Density Analyzer was used in the testing, and the test results are shown in Table 2. The average density of the KCl test samples ranged from 1.8 to 2.9 g/mL. According to Scomi Oiltools' guidelines on KCl quality characteristics, the density of the KCl test samples does not meet the standard. According to Scomi Oiltools, the ideal density of KCl should be in the range of 1.0–1.16 g/mL, as shown in Table 1. This is, of course, significantly different. It should also be noted that density is influenced by several factors, such as temperature and pressure. Crystalline materials like KCl can experience changes in density due to high temperatures. This is related to changes in their crystal structure. The same applies to pressure; pressure can affect the crystal structure of solid materials (Kasmungin et al, 2018).

Chloride (Cl⁻) Content Testing

Chloride content testing in KCl is performed using the Mohr precipitation titration method, which is based on the precipitation reaction of excess silver with potassium chromate (K₂CrO₄) as an indicator. In the Mohr method, the determination of chloride content in the sample takes place in a neutral environment with a pH of 6.5–8.0. If the test is conducted under acidic conditions, the concentration of CrO₄²⁻ ions will decrease. If conducted under basic conditions, a peroxide precipitate will form. During titration, vigorous and rapid stirring is also recommended to prevent Ag⁺ from oxidizing to AgO, which would prevent the titration endpoint from being reached (Rohmah & Rini, 2020).

The testing process began with the preparation of a 0.05 N potassium chloride solution. A total of 0.4 grams of the test sample of KCl was weighed and dissolved in "Aqua"-brand water in a 100 mL volumetric flask. The solution was stirred with a magnetic stirrer to ensure homogeneity. Once the solution was formed, 25 mL was pipetted into an Erlenmeyer flask, and 5 drops of a 5% potassium chromate indicator were added. The addition of potassium chromate turned the solution yellow. The solution was then titrated with a 0.282 N silver nitrate solution. Silver nitrate solution is highly sensitive to light; therefore, it must be stored in a dark container and protected from light. The AgNO₃ solution

used in this test was properly stored in a sealed black container. Next, the KCl sample was titrated with the AgNO_3 solution until the endpoint a brick-red precipitate was reached. The titration was performed in duplicate to ensure accuracy. The average volume of AgNO_3 used in the sample titration ranged from 4.8 to 5.2 mL, and the difference between the single and duplicate titrations was minimal, at most only 0.1 mL.

The silver nitrate solution will first react with the chloride ions in the KCl sample, forming white AgCl precipitates. This process continues as long as there are chloride ions available to be bound by Ag^+ to form AgCl. When all the chloride ions have reacted, the excess Ag^+ from the titrant will react with the potassium chromate indicator to form a brick-red precipitate of silver chromate (Ag_2CrO_4). This brick-red precipitate serves as the endpoint of the titration process (Day & Underwood, 1989).

Before proceeding with the calculations, the chloride ion concentration in the solvent (blank) was tested because the solvent used was not distilled water. The chloride concentration test on the solvent was performed using the same steps as for the test sample solution. The test results showed that a brick-red precipitate formed immediately upon the addition of the first drop of AgNO_3 solution, indicating that there were no chloride ions in the solvent, or that the concentration of chloride ions in the solvent was so low that it could not be detected by titration and could therefore be ignored.

After conducting the blank test, the process of calculating the chloride content in the samples was carried out; the results are shown in Table 2. The test results indicate that the chloride content of the KCl test samples ranged from 1,800 to 2,100 ppm. According to the KCl salt quality table by Scomi Oiltools, the chloride ion concentration in all tested KCl samples did not meet the standard. According to Scomi Oiltools, the ideal chloride ion content in KCl is at least 4,700 ppm by weight at 1%. As the sample weight increases, the chloride content should also increase (Scomi, 2008).

Turbidity Testing

Turbidity testing aims to examine the effect of the physical properties of KCl in the test sample when dissolved in water. Turbidity testing is also related to Total Suspended Solids (TSS). TSS indicates the total amount of substances present in a sample, including any impurities (Serajuddin et al., 2019). The relationship between turbidity and total suspended solids (TSS) has been extensively studied by previous researchers, typically using environmental samples. Several studies have demonstrated a significant relationship between the two, such as the study by (Khan et al., 2013) which reported a coefficient of determination between TSS and turbidity of 0.96; similarly, the study by (Kusari & Ahmed, 2013) reported a coefficient of determination between TSS and turbidity of 0.87.

The testing process begins by preparing a 5% KCl solution in a 100 mL volumetric flask. Next, an "auto zero" calibration is performed on the spectrophotometer using a blank. Before using the chamber, ensure it is dry and clean to optimize the testing process and achieve the best possible results. Once the calibration results show a value of zero, the testing phase can proceed to test the sample. The prepared 5% KCl sample solution is placed into the test chamber for testing. The test was repeated three times to ensure the accuracy of the results. If the results differed significantly from one another, the test was repeated starting from the stage of introducing the sample into the chamber, and the chamber was rinsed first. This could occur because it is likely that contaminants had previously adhered to the chamber walls, thereby interfering with the testing process. The results of the KCl sample turbidity testing are shown in Table 2. The turbidity test results show varying values across the 11 samples, ranging from 1 FTU to a maximum of 80 FTU. The KCl sample with the highest turbidity was KCl JM 2BB12021. The KCl JM 2BB12021 sample has physical properties that differ slightly from other KCl samples; specifically, it is darker in color and cloudy, resembling beach sand. This affects the turbidity value of the solution. When compared to the sample with the lowest turbidity KCl JM BC060037 the physical appearance of the two is very different. The KCl JM BC060037 sample has a white crystalline form, so when dissolved in water, it does not affect the solution's color. Based on this, it is known that the crystalline form of KCl can affect the color of the resulting solution, including its turbidity. Samples that are not pure white are presumed to contain many impurities, casting doubt on their purity. The same applies to the estimated TSS of the samples. The higher the turbidity value, the higher the estimated TSS in the sample (Serajuddin et al., 2019).

According to the Drilling Fluid Engineering Handbook from Scomi Oiltools, the quality standard for the turbidity of KCl when dissolved in water is less than 20 FTU. Based on this, all KCl samples met the standard, except for the JM 2BB12021 KCl sample, which had the highest turbidity at 80 FTU. The relationship between turbidity, TSS, and purity clearly indicates that the turbidity of a KCl solution signifies a high concentration of dissolved solids, which suggests that these solids are impurities that reduce the sample's purity; as expected, KCl is a white crystalline salt (Serajuddin et al., 2019).

Conclusion

Based on the test results, it can be concluded that the density range of the KCl samples is 1.9–2.9 g/mL. This does not yet meet the acceptable density range specified by Scomi Oiltools, which is 1.0–1.16 g/mL. Similarly, the results of the chloride content test on the KCl samples using argentometric titration fell within the range of 1,950–2,060 ppm. This also does not meet the acceptable range specified by Scomi Oiltools, which requires a minimum chloride content of 4,700 ppm for KCl. In the KCl turbidity test, all KCl samples met the standard, except for the KCl sample JM 2BB12021, which had the highest turbidity at 80 FTU. The turbidity limit for KCl, according to Scomi Oiltools, is less than 20 FTU.

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