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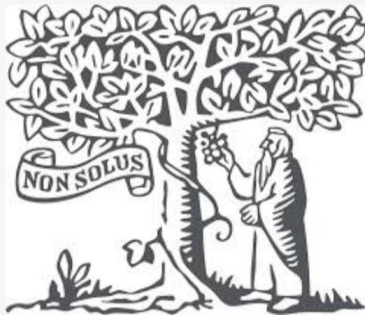
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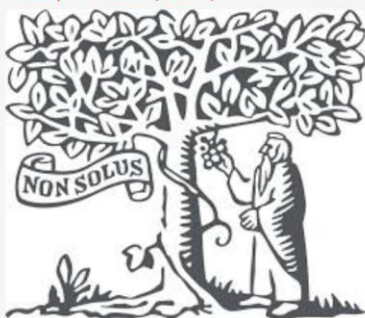
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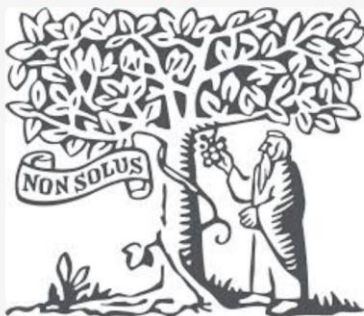
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The Residue Analysis Due to High Salinity of Produce Water Based Fracturing Fluid: A Laboratory Study

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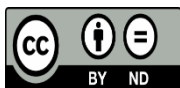


Keywords:

Residue, Viscosity, Salinity, Produced water, Fracturing fluid.

ABSTRACT

The residue created by water-based fracturing fluids is still a shortcoming in their application. This is related to formation damage induced by hydraulic fracturing. The use of water in the manufacturing of water-based fracturing fluids is one of the sources of the ensuing residue level. Production water has been extensively researched as a source of water for the production of fracturing fluids. Previous research has found that the presence of monovalent and divalent ions influences the viscosity of the fracturing fluid. Furthermore, dissolve ions in the produce water also increase the water salinity value. Based on these phenomena, more research is needed to determine the effect of dissolved ions and water salinity on viscosity and residue of produce water based fracturing fluid. An examination of the influence of produce water salinity on the residue was carried out in the laboratory using a centrifuge method. Residue testing was carried out after testing the viscosity and breaktime in a water bath at 70 0C. This study found that increasing the dissolved ion content in production water, both monovalent and divalent, reduces viscosity, but the resultant residue is still larger than when using tap water at the same thickener, crosslink, and breaker concentrations.



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1. INTRODUCTION

Since the conception of hydraulic fracturing, many fluids have been generated and tested as potential suites for specific formation types and even geographical areas. The most widely utilized hydraulic fracturing fluids nowadays are water-based. Because of their inexpensive price, accessibility, and ability to move proppants [1] into position to preserve fracture conductivity, they are preferred. The formation damage caused by the use of water-based fracturing fluids is one of the issues [2]. The presence of residue is one of the reasons of cause damage to this structure [3]. After the fracture process, residue is material that is no longer dissolved in the fracturing fluid. The type of thickener [4], crosslinker [5], [6], breaker, and other

additives used in water-based fracturing fluids affects the residue content [1], [7].

Thickening fluid types Guar gum and its derivatives are thickeners commonly employed in hydraulic fracturing fluids [4], [8]. Guar gum, also known as Guarana, Cyamopsis gum, Guarina, Glucotard, and Guyan, is a non-ionic, water-soluble polymer derived from the refined grain of cluster bean seeds. This type is more environmentally friendly, cost-effective, and simple to mix with different types of crosslinkers. The disadvantage of this form of thickening fluid is that it produces more residue than synthetic thickening fluids [8], [9]. Guar, a polymer with a long chain and a high molecular weight composed of mannose and galactose sugars, has been extensively used to viscosity water for hydraulic fracturing operations. An insoluble polymannose helix can be formed by as little as six continuous unbranched mannose units as in Guar. Guar is estimated to have up to 10% insoluble residue by weight, this early insoluble residue harms the proppant pack [10]. In addition to the polymer, the use of crosslinks and breakers will also affect the residue produced. The use of the right breaker can reduce the residue produced. Some types of breakers that have been used include Bromate, Ammonium persulfate, Acid, and enzymes. The use of enzyme breakers is reported to be the most effective in reducing residues, but there are limitations in the length of reaction time as well as the optimum pressure and temperature [11]. These fracturing fluid generated residues diminish the proppant pack's conductivity and formation damage in the invaded zone. Precipitation takes anywhere from a few hours to a few days to form [12].

Water-based fracturing fluid was initially developed using fresh water because it is compatible with additive addition and less damaging the formation [13]. However, considering the abundance of water sources originating from the oil or gas production process, various studies in recent years have focused on the use of produced water and flowback water as a material to make water-based fracturing fluids [14]. Also, the use of heavyweight brines as a basis for fracturing fluids is an efficient way for addressing the issue of excessive surface pressure during the deep well fracturing process [15]. Produced water has been investigated as one of the water sources used in the manufacture of fracturing fluids as a substitute for fresh water with a close-loop system. The use of this production water minimizes the construction of water tanks, and utilizes unused production water, making it more economical. Research conducted by [5] showed that the use of production water with polymers for recirculating fluid can minimize cost.

Aside from that, there is research attempting to use high salinity sea water as a fracturing fluid. It is tough to optimize fracture fluid viscosity in a high-medium salinity (e.g., saltwater and produced water) [16], [17]. The usage of different types of water will have an impact on the rheology and formation damage induced. Some factors that need to be considered in designing a fracturing fluid using production water, flowback water, or seawater include total dissolved solid (TDS), hardness, monovalent and divalent ion content. The amount of monovalent and divalent ions must be considered when make used of produced water-based fracturing fluid [18], whereas sulfate especially Na_2SO_4 ions can alter the rheology of seawater-based fracturing fluids with the carboxymethyl hydroxypropyl guar (CMHPG) polymer type [19], [20].

The high salinity and total dissolved solid (TDS) of seawater can cause problems with rheology and fluid stability at high temperatures as well as scale formation in the development of seawater-based-fracturing fluid [21], [22]. On other hand, based gel viscosity was not affected, but the crosslinking mechanism is less stable than fresh water whether hydroxypropyl guar (HPG) or carboxymethyl hydroxypropyl guar (CMHPG) polymers are used to make seawater-based fracturing fluid [22]. The rheological instability of the gelling fluid in the use of HPG and CMHPG polymeric fluids with seawater can be improved by replacing the polymer used with a polysaccharide gelling agent (PGA) with zirconium added as a crosslinker [23]. This polymer is stable in the temperature range of 150-325 °F. It also has excellent

proppant transport characteristics and provides a low residue content when broken. In other studies, the viscosity stability of the gelling fluid with seawater can be improved by the use of scale inhibitors [24] or chelating agents [20].

When compared to fresh water, employing produced water directly as a fracturing fluid increases formation damage [12]. This is due to the mineral deposition caused by the interaction of the produced water with the polymer utilized. In addition to polymers, the use of crosslinks affects the viscosity stability of the gelling fluid [5], [25]. Previous research has given several strategies to decrease the residue created, including diluting produced water [12], stabilizer additive [26], [27] and utilizing chelating chemicals [18]. According to the study conducted by [28], [29], the higher the residue will be higher the crosslinker concentration. This research uses tap water, hydroxypropyl guar (HPG) thickener, borate crosslinker, and bromate as breakers. The use of produced water as a fracturing fluid as a replacement for fresh water has been thoroughly investigated. [30], investigated the use of generated and flowback water as an alternative to tap water in a closed-loop system. This method of using produced water reduces the need for reservoir construction while also utilizing unused produced water, making it more cost effective. According to [31], using produced water with polymers for fracturing fluid can save it about \$1000 per year.

Based on prior studies, further research is needed about the impact of the water properties utilized in the fracturing fluid on the viscosity and residue generated. This study usage of production water that has high levels of salt, chloride, and salinity ions.

2. MATERIALS AND METHOD

2.1 Thickener and other additives

The thickener, Guar Gum, of industrial grade, was provided by PT. Bukitapit Bumi Persada, Indonesia. Low temperature crosslink and oxidizer as breaker were used in this formula of fracturing fluid. The crosslinker concentration used was 0.4% and 0.6% by volume, with breaker concentration of 2% by volume. The compositions of the fracturing fluid formula are shown in Table 1.

Table 1. Fracturing fluids formula

Sample name	Thickener concentration, ppt	Crosslinker, vol %	Breaker, vol %
A	40	0.4	0.2
B	40	0.6	0.2

2.2 Water samples

In this experiment, three type of water samples are tap water, de-ionized water, and produced water from one of oil field in Indonesia. The tap water and de-ionized water were used as a material for making synthetic brine, where the analysis reports of produced water sample are shows in Table 2.

Table 2. Composition of produced water

Ion type	Concentration, mg/L
Na ⁺	12,758
Cl ⁻	6,066
Ca ²⁺	26,800
Mg ²⁺	6,120
Salinity	19,700

The content of Na⁺ and salinity of the formation water was relatively high. According to the water analysis reports, the sodium chloride (NaCl) was selected and added to the tap water to prepare the de-ionized water as synthetic brine. To prepare de-ionized water a certain amount of NaCl was added to 1 L of tap water and stirred using an agitator for 30 minutes. The salinity of synthetic brine were 10,000 ppm and 20,000 ppm.

2.3 Preparation of based fracturing fluid

There were four based fracturing fluids with different water salinity. Each based fracturing fluid was prepared with same method. 40 ppt of thickener was added into 1 L tap water, de-ionized water (salinity 10,000 ppm and 20,000 ppm), and produced water. The fluid was mixed at 1000 RPM using agitator for 20 min. Following that, 0.4% or 0.6% crosslinker was added and mixed. 100 mL sample were used for the viscosity test using Fann VG meter at 300 RPM. Liquid gel breaker, clay stabilizer, and buffer were added directly to the final fracturing fluid sample.

2.4 Residue test

A 100 mL fracturing fluid samples heated in a water bath at 70°C until break. Then, separation process places the sample in the centrifuge tube, seal it, and spin it for 30 minutes at 300 RPM. Examine the resulting residue visually. The residue should then be filtered using filter paper with pore sizes of 2.5 micrometers and dried in an oven at 100 °C for 30 minutes. Weigh the dry residue and then use the following calculation to compute the resulting residue:

$$\text{Residue} = \frac{\text{weight of dry residue}}{\text{volume of fracturing fluid}} \text{ mg/L} \tag{1}$$

3. RESULTS AND DISCUSSION

3.1. Viscosity of based fracturing fluid

Increasing the Na⁺ ion concentration in tap water to 20,000 ppm resulted in increased viscosity as shown in Figure 1. These findings are congruent with those of [12], [5]. However, the viscosity drops in produced water with salinities near to 20,000 ppm. This is due to the presence of more complicated ions in the production water, such as divalent ions: calcium and magnesium (Ca²⁺ and Mg²⁺).

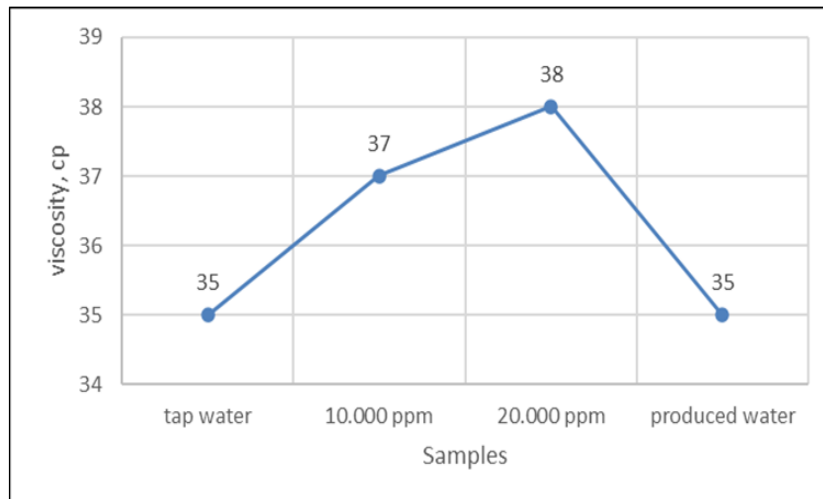


Figure 1. Viscosity of the fracturing fluid using tap water, DI water salinity 10,000 ppm, DI water salinity

20,000 ppm, and produced water

[12], did study that investigated the viscosity of the fracturing fluid using production water directly and then compared it to utilizing fresh water, dilution of 25 times the production water. According to this study, using production water directly leads in a decrease in the viscosity of the fracturing fluid as compared to fresh water. Dilution is required to obtain high viscosity. Dilution is used to reduce the number of divalent ions (Ca^{2+} and Mg^{2+}). In order to obtain high viscosity. Reduced Ca^{2+} ions result in increased viscosity, whereas reduced Mg^{2+} has no effect. The interaction of Mg^{2+} ions with the polymer's hydroxyl groups has no influence on the polymer's dynamic radiation and has no effect on the hydration of the guar polymer.

3.2 Residue of fracturing fluid

Figure 2 showed that the Na ion concentration increased the residue compared with the base line using tap water. This shows that the solubility of monovalent ions influences the breaking process of the thickener. It can also be concluded that the solubility of NaCl in tap water exceeds saturation, thereby increasing the resulting residue. Whereas in the production water samples, the residue produced was still higher than the tap water samples but lower when compared to the DI water samples, both with salinities of 10,000 ppm and 20,000 ppm, respectively.

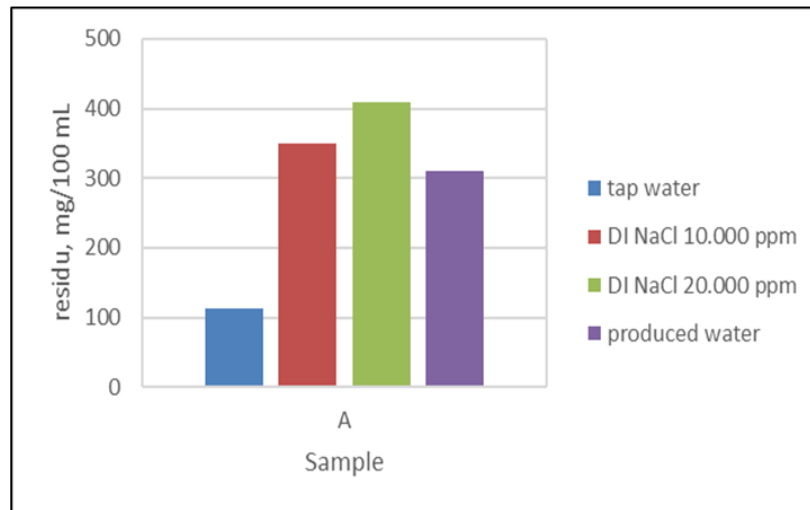


Figure 2. Residue of the fracturing fluid with 0.4% crosslink and 0.2% breaker using tap water, DI water salinity 10,000 ppm, DI water salinity 20,000 ppm, and produced water

3.3 Residue of fracturing fluid due to crosslinker

Furthermore, at a crosslink concentration of 0.4%, the viscosity produced by the tap water sample and production water are the same, but the production water sample creates 64% more residue. The residue formed by production water is the result of a shortage of breakers. According to the findings of [25], who compared the concentration of Guar gel to the needed breaker. As the concentration of Guar utilized increases, so does the concentration of breaker. At a Guar concentration of 30 lb/1000 Guar gel, approximately 2 ppt of oxidizer breaker is required to create the same residue as utilizing a lower concentration of Guar. The results comparison about residue of fracturing fluid due to crosslinker is shown in Figure 3.

The tap water and production water samples showed results consistent with research by [28], which stated that the increase in residual content was directly proportional to the crosslink concentration used in the fracturing fluid. However, the results of the DI sample testing for water with a salinity of 10,000 ppm and

20,000 ppm with different crosslink concentrations showed that the increase in crosslink concentration was inversely proportional to the residue produced. At a concentration of 0.6%, there was a decrease in residue in the DI water salinity samples of 10,000 ppm and 20,000 ppm by 44% and 15% respectively. This shows that the ion content, both monovalent and divalent, in the water affects the residue produced. When water only contains monovalent ions, it will increase the residue produced, different if the presence of monovalent ions is followed by the presence of divalent ions it will decrease the residue produced.

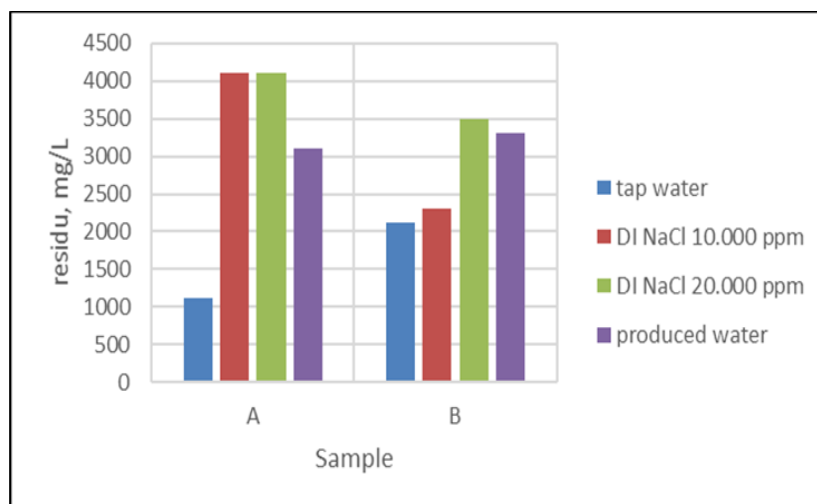


Figure 3. Residue comparison between 0.4% and 0.6% crosslink in tap water, DI water salinity 10,000 ppm, DI water salinity 20,000 ppm, and produced water fracturing fluid.

4. CONCLUSIONS

From the result and discussion above, it concludes that:

1. Water salinity by adding NaCl to tap water increases the viscosity value and residue produced.
2. Using production water (19,700 ppm) reduces viscosity and residue when compared to using tap water with a salinity of 20,000 ppm.
3. The residue generated by the use of production water is affected by the concentration of thickener, crosslinker, and breaker used.
4. Increasing the dissolved ion content in production water, both monovalent and divalent, reduces viscosity, but the resultant residue is still larger than when using tap water at the same thickener, crosslink, and breaker concentrations.
5. Further research is needed regarding the effects of divalent ions in residue formations.

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