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Effect of Silicon Oxide Nanoparticles and Brine Salinity on Fines Migration in an Unconsolidated Formation

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ABSTRACT

Migrating fines are usually the source of near wellbore formation, flow paths and far away into the reservoir damage, which are due to collection of these clayey fines in pore throats of the different flow paths existing inside the hydrocarbon bearing formation. Protection of these regions from damage encourages high recovery. Hydrophobic silicon oxide nanoparticles (NPs) as well as a sharp change in the brine salinity of the unconsolidated environment was applied to a simulated unconsolidated formation. The results obtained showed that at high concentration of hydrophobic silicon oxide nanoparticles and high salinity brine (30g/L), fines creation and migration was drastically reduced but at low concentration of hydrophobic silicon oxide nanoparticles and low salinity brine (0.5g/L) more fines were created and mobilized. The presence of hydrophobic silicon oxide nanoparticles in high salinity condition in unconsolidated formation is effective in controlling the amount of clay fines created and migrated in unconsolidated formations.

1. INTRODUCTION

Fines migration is a noticeable problem in petroleum production engineering; Fines are tiny particles existing inside a hydrocarbon bearing rock formation, formed when reservoir fluids start flowing from one location to another and when the *in-situ* brine salinity conditions of the formation changes. Fines can be of grains sand from the reservoir sand stones, silt or clay materials deposited along with the grains and reservoir fluids. A reservoir has these materials attached to the walls or surface of the grains due to cementation and compaction, and some of these materials may detach during the production life of the reservoir. Reservoir hydrocarbon bearing rock formations are a combination of different materials cemented together. The materials include different sizes of sand grains, clayey materials (kaolinite, chlorites, smectites, quartz and carbonate type), silts, etc. The fines particles may be as a result of the introduction of drilling mud, other input activities, or due to the release by the pushing filtrate into the porous throat in the porous environment (Sensoy *et al.* 2009). Some of the authigenic clayey minerals which does not expand e.g. koalinite, chlorites etc. and some expanding authigenic clay minerals e.g. smectites, quartz, and carbonates orientation clayey fines particles have been identified to migrate from one location of the porous environment to another (Jilani *et al* 2000).

The formation can retain and allow the flow of a certain volume of the hydrocarbon because of its physical properties resulting from the grains arrangement at the point of deposition and cementation. The degree of cementation of the grains and other materials available in the formation determines its consolidation (Civan, 2007). A formation can either be consolidated or unconsolidated formation. It is consolidated when all the materials involved are well cemented such that it does not easily allows the detachment of finely grains particles (Civan, 2007). Ochi and Vernoux, (1998) inferred that in unconsolidated formations, detachment of finely grains (especially clays) from the walls of the grains are highly encouraged by weak cementation existing inside the formation. Consequently, the fine grains from clayey materials are easily carried by flowing fluids especially at high flow rates from their point of detachment through reservoir pores, through the perforations and wellbore, as well as into production and surface facilities. Unconsolidated reservoir formations are therefore the source of infinite supply of fines and sands that are produced during hydrocarbon exploitation (Ogolo, 2013). Production from unconsolidated formations will always be encountered, meaning clayey fines particles will continue to move from source locations to the near wellbore region, consequently leading to flow problem due to formation damage.

Different studies have been conducted to find ways to control the creation and migration of formation fines and to remove the concentrated formation fines in the near-wellbore region to reduce skin (Habibi *et al.*, 2012; Ogolo *et al.*, 2012; Igbinere *et al.*, 2015). Some processes have been proposed to reduce the formation brine salinity impact on fine grain particles generated inside the reservoir due to fluid flow (Khilar *et al.,* 1983). According to Oruwori and Ikiensikimama (2010) typical salinities of sandstones reservoirs including some in Niger Delta fall within the range of 5g/L for low salinity to 30g/L and above for high salinity, this is also equivalent with the 3wt% (0.51 M) adopted as high salinity (Khilar and Fogler 1984). Different acid systems were developed to remove the formation fines that plugged pores in the near-wellbore region, gravel packs, and sand control screens for different down-hole conditions (Hibbeler *et al.*, 2003, Huang *et al.*, 2010). Hadfield *et al.* (2007) provided completion methods like sand-exclusion method to reduce fine producing from sand face in high-fines-content gas zones.

This study thus focused on the influence of formation brine salinity due to the sharp change in the salinity of brine and the application of hydrophobic silicon oxide nanoparticles in the unconsolidated formation so as to control the production and migration of fine particles in an unconsolidated formation.

2. MATERIALS AND METHODS

The fluids used were low salinity brine (5g/L), high salinity brine (30g/L) and 700 ml of ethanol. 1.5g, 1.0g and 0.5g of hydrophobic silicon oxide nanoparticles (NPs) were used to prepare concentrations that were applied to the simulated unconsolidated porous formation. The hydrophobic silicon oxide nanoparticles have a particle size of 10–20 nm with a surface area of 100–140 m^2/g, a bulk density of 0.15 g/ml and a pH range of 6.5 – 7.5. Consequently, it can only be dispersed in non–polar and weak polar organic solvents. A porous media was prepared from glass beads by agitation and compaction in a known diameter under pressure. The simulated porous formation was saturated with brine (Potassium chloride KCl) of low salinity (5g/L) and then high salinity brine (30g/), while the hydrophobic silicon oxide NPs was dispersed in ethanol fluid.

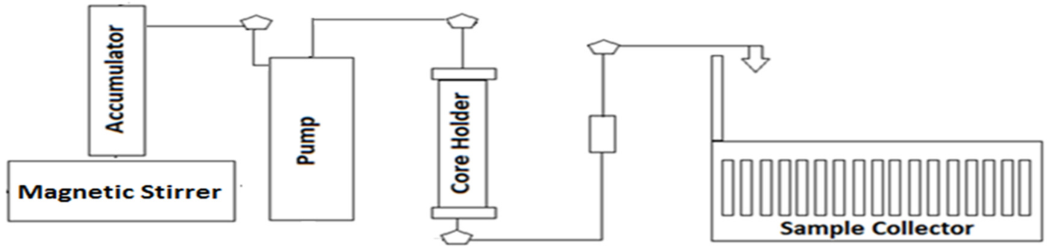

Figure 1: Experimental set-up of the simulated unconsolidated formation (Igbinere *et al* 2015)

Glass beads were evenly mixed with 20%wt of dry kaolinite (fines) to prepare the unconsolidated formation. Figure 1 is the experimental set-up which shows the fluid flow pattern from the accumulator through the core holder containing the simulated porous media from glass beads. Eldex (Optos) pump was used to inject low salinity brine into the unconsolidated porous environment to saturate it. Hydrophobic silicon oxide was then dispersed in ethanol and injected through the porous environments containing glass beads and fines saturated with brine. The produced effluent was meticulously monitored and collected into a beaker as shown in Figure 1, filtration processes were applied to extract the fines produced. The process was repeated at various flow rates for the same concentration of nanoparticles (NPs). Also, the procedures were repeated for high salinity (30g/L) brine of KCL and results were recorded.

3. RESULTS AND DISCUSSION

The different fluid flow experiment generated the effluent fines in grams (g) for low and high salinity brine at different concentration of Nanoparticles (NPs) as shown in Figures 2 to 4. Figure 2 shows the correlation between mass of effluent fines produced under different flow rates when 0.5g of nanoparticles was used for low and high salinity brine. The correlation clearly suggest that the produced fines is depends on brine salinity inside the formation, as fines produced increased with decrease in brine salinity. When the *in–situ* conditions favours low salinity, more fines are encouraged to detach and migrate from the source grain towards the wellbore. The results in Figure 2 agree with those of Vaidya and Fogler, (1990) who observed that low salinity causes fines to be released which, in turn, causes a drastic decline in the permeability of the reservoir. However, at high brine salinity, fines detaching from the unconsolidated formation are at its lowest ebb. Similar results were also observed as shown in Figures 3 and 4. Figure 4 indicated little or no change in the volume of clay fines at the effluent, this is due to the presence of high concentration of hydrophobic silicon oxide NPs and high salinity brine (30g/L KCL).

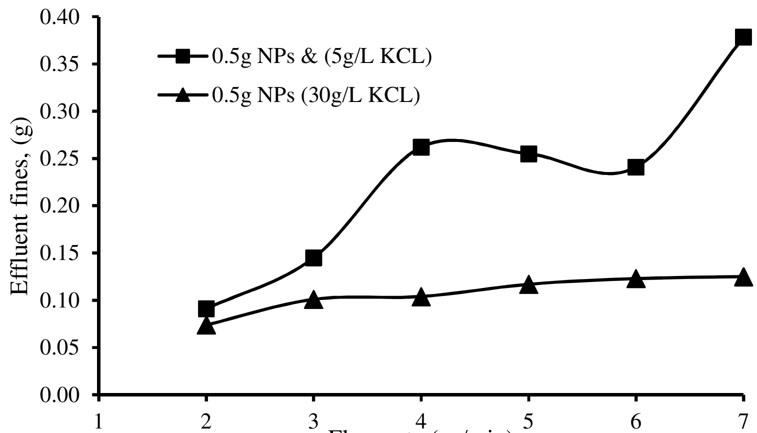

Figure 2: Produced fines for low and high salinity at 0.5g of hydrophobic silicon oxide NPs

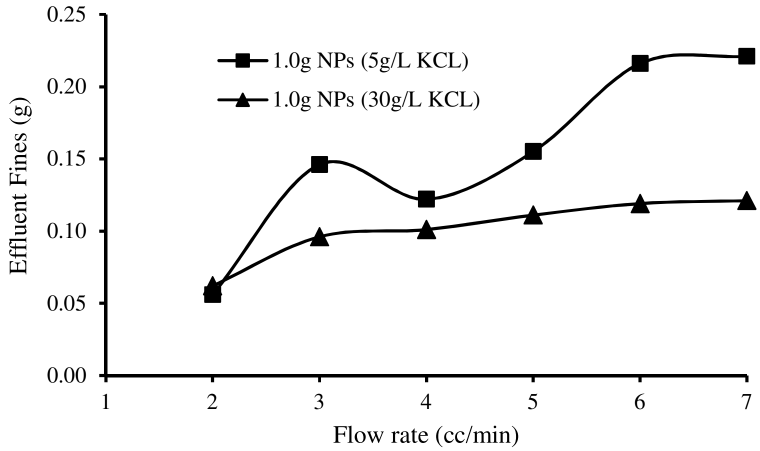

Figure 3: Produced fines for low and high salinity at 1.0g of hydrophobic silicon oxide NPs

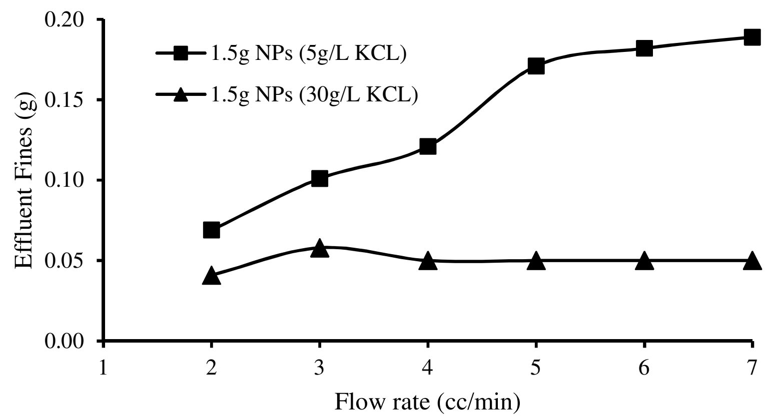

Figure 4: Produced fines for low and high salinity at 1.5g of hydrophobic silicon oxide NPs

In Figure 4, it is seen that higher flow rate would have resulted in the production of more fines, however, the fines produced when flow rate increased remained constant. This shows clearly that at higher salinity, the effect of hydrophobic silicon oxide NPs became even more pronounced in terms of controlling fines production in an unconsolidated formation. These results also suggest that a continue increase in the volume of fluids produced from the unconsolidated formation increases the amount of fines produced at lower brine salinity and reduces as brine salinity increases. When the primary energy of the reservoir has been depleted due to production of hydrocarbon from that reservoir over period of time, consequently, secondary energy can be introduced into the reservoir so as to recover more hydrocarbon. Low salinity can be introduced into the formation during this process of secondary energy introduction for example flooding (secondary recovery). Also, it can be introduced during drilling and completion of the well, because the initial condition inside the reservoir or the salinity of the brine displaced by hydrocarbon during crude oil migration was high. The incoming of other fluids from a different environment reduces the salinity of the brine. In Figures 2 to 4, it can also be seen that a sharp increase in the salinity of brine from 5g/L (low salinity) to 30g/L (high salinity) resulted in the decrease in fines created. Blume *et al.* (2005) stated that there is a critical salt concentration (CSC) below which fine particles are created and mobilized, and above it, the fine particles remain fixed to the grain walls. At low brine salinity (5g/L), which is below the CSC, more fines were created and mobilized in the presence of hydrophobic silicon oxide NPs, while at high brine salinity (30g/L) which is above the CSC less fines were created and mobilized as shown in Figures 2 to 4.

4. CONCLUSION

The results obtained from this study showed the effects of salinity and nanoparticles (silica oxide) on the fines production. The following can be drawn as conclusions.

1. The presence of hydrophobic silicon oxide nanoparticles in high salinity condition in unconsolidated formation is effective in controlling the amount of clay fines creation and migration in unconsolidated reservoir.

2. The sudden change in the salinity of brine from high salinity to low salinity in unconsolidated formation create fines for migration.

5. ACKNOWLEDGEMENT

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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