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THE EFFECTS OF MAGNESIUM OXIDES NANOPARTICLES IN FINES CREATION AND MIGRATION IN SYNTHETIC AND RESERVOIR SANDS POROUS FORMATIONS

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Abstract

Fines creation and migration in reservoir environment have been a source of formation damage in oil reservoirs and consequently, a major cause for reduced oil production over the years. Formation fines are unconfined solid particles present in the pore spaces of the formation. The migration of fines due to fluid flow in the reservoir causes pore plugging and permeability reduction, in recent times many studies have been carried out for the characterization of fines and their migration effect on permeability reduction, this work emphasis the effects of magnesium oxides nanoparticles in remediating the problem of fines creation and migration from the source rocks through the interconnected pores spaces. A packed column of synthetic glass beads materials and reservoir sands obtained from Niger Delta were utilized to simulate porous reservoirs environment which contained clay materials commonly existing in reservoir and which were soaked with magnesium oxides nanoparticles to achieving the adequate cementation of the synthetic glass beads and the reservoir sands with their respective clay fines materials. Four types of nanoparticles dispersing fluids were adopted, they are; ethanol, diesel, high salinity brine and a mixture of ethanol and diesel. The effluents fines particles breakthrough had an average of 86.6% reduction from reservoir sands to glass beads in the blend of ethanol plus diesel, suggesting that more of the fines are trapped inside glass beads media, however, less fines are trapped inside a reservoir sand media. Furthermore, an average of 71.2% increase was recorded in the effluents fines from reservoir sands to glass beads in high salinity brine, indicating that high salinity brine support the control of fines. The results further indicate that dispersing magnesium oxides nanoparticles in the right dispersing fluid can effectively control fines migration by sticking the fines to the porous media thereby hindering their generation and movement in the near wellbore area of the oil reservoir.

Keywords: Magnesium Oxide, Nanoparticles, Glass Beads, Reservoir Sands, Kaolinite, Ethanol, Diesel, Brine Salinity, Effluents

1.0 Introduction

The flow of reservoir fluids from any location of the reservoir towards the near wellbore and towards other sections of the reservoir has always been characterized with different problems which have so many implications on the subsurface formations and surface facilities. These problems have been viewed, analyzed and technically argued in different ways that led to the application of several approach in addressing these problems. The different perspectives in finding solutions to these problems have created other unforeseen challenges which have skilfully questioned these processes in obtaining these solutions and the recommended solutions [1]. Formation damage is one major challenge encountered in the production of oil and gas which arises in subsurface reservoir due to activities such as drilling, hydraulic fracturing, work-over operations, production, thermal recovery etc. and these activities encourage the creation and migration of clay fines which consequently damage the formation. Formation damage due to fines migration has always been a major problem to handle in the production of oil from reservoirs. Porous media clayey fines, light weighty or weightless particles are described as unattached finely light weight solid particles available inside the porous environment, their continued change in position due to fluid flow in the porous hydrocarbon environment lead to blocking of the pore throat and the elimination of permeability [2]. The fluid inside the reservoir moves towards the wellbore, the fluid velocity increases what is more at

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a critical velocity these fines can be picked up into the fluid and move with it. These fines are captured by porous media and block the pore throat area causing plug of the flow path which leads to productivity decline as shown [3]. Fines particles are described technically as loosely, light weighty, weakly attached and unconsolidated clayey particles in a setting range of particulate sizes which can successfully move with flowing phase fluid thereby bringing about porous media connectivity damage as a result of sieving activities of the porous media [3,4,5]. Formation damage is the inability of the flow channels to allow and deliver fluid from one point of the formation to another. This elimination of pore medium connectivity is mainly due to fines movement associated with the ionic changes induced into the reservoir during subsurface operations. The unconsolidated fine particles which are stacked to the walls of the pore space produce a state of equilibrium involving the porous environment fluids. However, "variations in chemical, thermodynamic, and stress states may create non equilibrium conditions and induce the salinity, velocity, and thermal shock phenomena and particle detachment and precipitate formation" [5]. This depositional era systematic state is inherent as regards the surface plain of the walls of the porous grains environment and with the flowing phase fluid(s), a disturbance of this condition by the introduction of primary, secondary, or better recovery approaches leads to the dissolving of the mineral-substances which spring out the aqueous phase ions of so many kind and the clayey fines which are weakly fixed particles attached to the grain surface are set free into the streams phases. The ionic presence, also inclusive of light weighty fines particulates, moves with the flowing fluid; this allows some forces of interaction to exist between these particles, ions, or with the fluids to creating porous media problems. "The composition of petroleum bearing formations study by [6,7] revealed that formations basically contain various mineral oxides such as SiO_2, Al_2O_3, FeO, Fe_2O_3, MgO, K_2O, CaO, P_2O_5, MnO, TiO_2, Cl, Na_2O, which are particles in nature, forming the porous matrix of the porous media. Different NPs were investigated in controlling fines [2] MgO NPs recorded the highest adsorption percentage in porous environment when compared with silica and aluminium oxide nanoparticles. Zeta potential was study when MgO NPs was used to treat fines migration [8] and the effects of MgO NPs in reducing fines migration in reservoir sands was successfully modelled. The effect(s) of "MgO NPs introduction into water sensitive porous environment media to advert permeability problems, by applying sandstones from Berea geological environment, stability was achieved uniformly, the communication between the energy in the NPs and dispersion concentration was determined with the use of DLVO theory [9]. used various silica nanofluid in reduction of fines migration and surface modification of Berea sandstone and nanoparticles in the order of average 10 nm (SiO_2 ranges from 5 to 15 nm and MgO ranges from 30 to 40 nm) were used to prevent fines migration while producing, because of their small size compared with the pore throats size, nanofluid does not have any effect on blockage of pore throats or reservoir permeability [3,10]. In this work, emphasis was given to the application of magnesium oxides (MgO) nanoparticles in the cementation of fines to synthetic porous materials and reservoir sands, consequently, preventing these fines from migrating to other locations of the porous environment. Also, different grain sizes were adopted to investigate the effects of magnesium oxide nanoparticles with porous media having varying reservoir characteristics in preventing the problems associated with clay fines commonly found in reservoir environment.

2.0 Materials and Methods

Magnesium oxides nanoparticles (MgO NPs) was selected and investigated because of its unique properties. This compound is made up of magnesium and oxygen with composition of 60.29% magnesium and 39.67% of oxygen. Magnesium can best be described as chemical substances with symbol Mg having an atomic number 12 with a coating ability comprising of $MgCO_3{\cdot}Mg(OH)_2$, also, it gives a good property that encourages high performance in the fixation of migrating fines [11]. In its nanoparticles form, it is viable in the attraction of negatively charged fines particles found in the reservoir formation. It has a very high surface energy due to its high surface area, and high porosity quality. This surface area gives it the ability to spread over the grain surface effectively and leads to the retaining of more migrating fines particles in porous media.

2.1 Experimental Procedures

Four different dispersing fluids were adopted for this investigation and3g/L of MgO NPs was measured and mixed with the dispersing fluids. The four dispersing fluids were 30g/L of high salinity brine, ethanol, diesel and a blend of diesel and ethanol. The reservoir sand was thoroughly washed and dried in an oven for several hours at 100 ^{o}C, the sand sieve analysis was carried out to determine the different ranges of sand grains available, this was randomly and carefully mixed together in the percentage ratio of 20% for the bigger sand grain sizes (-16 +18 mesh), 40% for the medium sand grain sizes (-20 +35 mesh) and 40% for the smaller sand grain sizes (-50 +60 mesh). These sorting arrangements gave it the unique features similar to that of a reservoir, because a reservoir is a combination of different sizes of grains, different shapes and texture etc. The class IV glass beads were also applied to simulate a porous media. Here, two types of glass beads were adopted, which were similarly mixed together randomly and carefully in the percentage ratio of 50% for the bigger grain sizes of glass beads (-20 +35 mesh) and 50% for the smaller grain sizes (-50 +60 mesh). The different grain sizes adopted for both the reservoir sands and the class IV glass beads was due to the fact that mixed sorting arrangement affects the trapping mechanism of nanoparticles (NPs) and the resulting porosity. The lithology of the reservoir model system was condition by the introduction of kaolinite clayey fines particles gotten from Niger Delta formation precisely from Benin formation. 0.5 wt% of kaolinite fines of 230 mesh (63 microns or 0.063 mm) was thoroughly mixed with the reservoir sand grains and the glass beads which falls within the ranges of fines particles sizes. The sands and glass beads were soaked for a minimum of 48 hrs with the different dispersion fluids already mixed with MgO NPs, i.e. 0.3 wt% (3g/L) of MgO NPs was dispersed with the four different fluids; diesel, ethanol, high salinity brine 30g/L (sodium chloride NaCl) and diesel-ethanol blend. Furthermore, reference experiments were also designed by using these dispersion fluids to soak the sands and glass beads without MgO NPs so as to ascertain the level of performance of the different magnesium oxide nanoparticles in the reservoir sands and class IV synthetic glass beads.The experimental set up is as shown in figure 1, low salinity brine of 4.09 g/L [12] was injected into the porous media to create a sharp environmental change inside the porous environment that allows the release of fines particles since the fines have been prepared in such a way to stick with the sand and glass beads surfaces. The brine was injected at varying flow rates of 2 ml/min, 3 ml/min, 4 ml/min, 5 ml/min and 6 ml/min with each flow rate allowed for a period of 5 minutes. The effluents were collected for analysis and the pH of the different effluents was digitally measured and with the aid of filter paper the mass of fines particles produced at the effluent was also measured using equation 1.

Mass Difference (g) = Final Mass (g) – Initial Mass (g) (1)

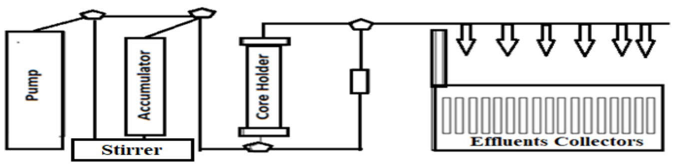

Figure 1: Schematic for the Fluid Flow Experimental Set-up

3.0 Results and Analysis

The results presented in tables 1 and 2 shows the effects of magnesium oxide nanoparticles with the different dispersing fluids for reservoir sands and synthetic class IV glass beads. At the reservoir conditions, magnesium oxides nanoparticles were able to trap more clay fines at high salinity and low flow rates. This is attributed to the presence of high salinity inside the media, because this condition favours the fixation of fines particles to the surface of the different grains sizes used in simulating the porous media. High salinity encourage fixation in reservoir environment, it can also be shown from the results that as the fluid flow rate increases the fines collected at the effluents also increases. However, the produced fines at the effluents collection section reduce at higher flow rates in the presence of MgO NPs trapping the clay fines inside the porous environment and consequently controlling the impact on reservoir permeability, without NPs low pH and high flow rate lead to permeability reduction [13].

Table 1: Effluent Fines Obtained in Reservoir Sands Soaked with MgO NPs

Flow Rate, (cc/min)	Mass of Effluents Fines (Diesel), (g)	Mass of Effluents Fines (Ethanol), (g)	Mass of Effluents Fines (High Salinity Brine), (g)	Mass of Effluents Fines (Ethanol+Diesel), (g)
2	0.015	0.018	0.005	0.066
3	0.009	0.080	0.010	0.058
4	0.009	0.005	0.016	0.019
5	0.020	0.023	0.022	0.048
6	0.005	0.001	0.002	0.064

The results obtained with glass beads differs from the results obtained with reservoir sands, as more clay fines were collected at the effluents for reservoir sand media, meaning more of the clay fines were fixed to the glass beads with MgO NPs and it is due to the fact that the reservoir sand media created a more compacted reservoir with tight cementation of the grains with the MgO NPs and the various dispersing fluids. Consequently, the environmental conditions for sand media favoured less fines to be retained in the porous materials. The nanoparticles was able to trap some of the clay fines, suggesting that MgO NPs is good in controlling the creation and consequently the migration of clay fines materials commonly found in oil reservoir formations. The different fluids applied in dispersing the magnesium oxide nanoparticles impacted differently on the formation and migration of fines in glass beads and reservoir sands, this is seen from the results presented in tables 1 and 2. The sorting of the grain sizes used in simulating the porous environment either for the reservoir sands or class IV glass beads also contributed to the quantity of the clay fines that finally arrived at the effluents collection section because, in table 1 the effluents recorded for the diesel dispersing fluid are lesser than the effluents presented for diesel dispersing fluid in table 2. However, this is not obvious when ethanol was used as a dispersing fluid. Furthermore, more fines were trapped inside the reservoir sand media when high salinity was used to disperse MgO NPs as presented in table 1 than glass beads media shown in table 2.

Table 2: Effluent Fines Obtained in Glass Beads Soaked with MgO NPs

Flow Rate, (cc/min)	Mass of Effluents Fines (Diesel), (g)	Mass of Effluents Fines (Ethanol), (g)	Mass of Effluents Fines (High Salinity Brine), (g)	Mass of Effluents Fines (Ethanol+Diesel), (g)
2	0.015	0.015	0.024	0.006
3	0.011	0.021	0.076	0.006
4	0.073	0.043	0.042	0.007
5	0.016	0.023	0.034	0.003
6	0.067	0.001	0.028	0.003

The migrating fines particles breakthrough was low in some cases as presented in the blend of ethanol plus diesel in table 2 compared to the same dispersing fluid in table 1, suggesting that more of the fines are trapped inside glass beads media, however, less fines are trapped inside a reservoir sand media. This may be connected to the fact that the use of reservoir sands soaked with magnesium oxide nanoparticles (MgO) NPs dispersed with the blend of ethanol plus diesel in simulating a porous media created a more tightly porous media, which may be due to the shape, size, texture and possibly the pattern of network system created with the reservoir sands. The spread of ethanol plus diesel dispersed MgO NPs over the grain surfaces allowed the sands to retain less of the fines particles introduced into the sand media. While more were retained inside a glass beads media soaked with ethanol plus diesel dispersed MgO NPs.

4.0 Conclusion

The results obtained and presented in previous section followed by the observation and analysis enumerated, the following inference were drawn

1. The application of magnesium oxide nanoparticles in reservoir sands and in synthetic class IV glass beads porous media is very effective in controlling the creation and migration of clay fines.
2. Simulation of porous media with synthetic class IV glass beads encourages magnesium oxide nanoparticles to retain more clay fines when compared with reservoir sands porous environment.
3. Magnesium oxide nanoparticles are more effective in preventing the generation and migration of clay fines when dispersed with high salinity brine in porous environment.

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