© NOV 2025 | IRE Journals | Volume 9 Issue 5 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV9I5-1712333

The Use of Periwinkle Shell Nanoparticle in Water Based Nanofluid for Displacement of Crude in Enhanced Oil Recovery

EROMOSELE ABUMERE[1], AUSTIN EMMANUEL EBIRIEN[2]
[1, 2]*Department of Industrial Safety and Environmental Engineering Technology, Federal Polytechnic of Oil and Gas Bonny, Rivers State, Nigeria*

Abstract- Experimental technique was used in the investigation of periwinkle shell-characterized nanosized particles in the production of water-based nanofluid used to displace crude oil for the purpose of altering oil wettability and to enhance oil recovery. Three samples of nanofluid with varying nanosized particles volume fractions were used in the injection flooding. Effects of wettability were ascertained, the oil displacement flow rate due to nanofluid flooding was obtained and compared with the displacement flow rate of a pure sample of water flooding, and the effect of nanoparticles on surface tension was also ascertained. Numerical results presented in tables show that the wettability of oil is reduced by the addition of nanosized particles of periwinkle shell. Results also revealed that there is a relatively higher displacement of oil using nanofluid flooding than the displacement of oil observed for pure water samples. Results presented further reveal that the surface tension of crude oil is reduced by the addition of nanosized particles. The implication of our findings in this study is that nanofluid made from the characterization of periwinkle shells provides an environmentally friendly solution to the challenges of elevating production capacity from carbonated crude oil reservoirs.

Index Terms- EOR, Periwinkle shell, Crude oil, Nanofluid, Nano size-particle

I. INTRODUCTION

Nanofluid has shown significant contributions towards the enhancement of the oil recovery process from carbonated reservoirs. Common recovery techniques have failed to recover a greater percentage of oil remnants in a carbonated reservoir. Researchers have recommended several techniques, like the wettability alteration mechanism of rock formations of carbonated reservoirs. Nanofluid has also been shown to influence the pressure mechanism of the disjoining structure of the enhanced oil recovery process [1- 6]. The chemical-enhanced oil technique has been used to reduce mobility ratio, altering wettability, which has provided a solution to some of the extraction using both the secondary and primary recovery techniques [7 – 10].

Hydrophilic silica nanoparticles with an average primary particle size of 7 nm were selected for the experimental inquiry. Synthetic reservoir brine was used to create nanofluid, and the injection method related to nanofluid flooding was carried out as a secondary recovery procedure. The results show that oil recovery onto Berea cores is nearly 8% greater when nanofluid flooding is applied. Additionally, at the core size, the nanofluid decreased residual oil saturation in the range of 2–13% of pore volume (PV). Additionally, our studies' findings demonstrated that nanofluid flooding has a greater potential to enhance secondary oil recovery than tertiary recovery [11]. Parameters related in the recovery mechanism of crude oil under electromagnetic waves, such as reducing mobility ratio, lowering interfacial tensions (IFT), and altering wettability, were examined. Using the two-phase displacement tests, which were conducted in sandpacks under the water-wet environment at 95°C, with permeability in a spectrum of 265–300 mD. ZnO nanofluids with two distinct particle sizes (55.7 and 117.1 nm) were created using 0.1 wt of crude oil from the Tapis oil field. percentage of nanoparticles that dispersed using SDBS as a dispersant in brine (3 weight percent NaCl). The study's findings show that electromagnetic-assisted nano flooding increases oil recovery by roughly 9–10.4% of OOIP. These findings suggest a viable method for using water-based ZnO nanofluid for improved oil recovery [12]. Using the Visualization flooding experiments approach with a glass micromodel, the research was conducted to observe how nanoparticles displaced crude oil behavior in pore level as well as nanoparticles adsorption and retention inside porous media. The study revealed that nanoparticles have promising potential for enhanced oil recovery in the future. Based on the results of the nanofluids used in this experimental work, the mechanisms of wettability alteration may be the most important and main enhanced oil recovery mechanism for nanofluid flooding [13]. Based on a micromodel experiment, the pore-scale performance and mechanism of nanofluid for increased oil recovery were examined using experimental technique. Additionally, the study's findings showed that nanofluid injection significantly improved oil recovery performance. The wettability of the oil-bearing pore wall is observed to change from a strongly water-wet condition to a neutrally wet condition in the presence of nanoparticles through examination of the precise pore-scale fluid circulation [14]. In a bid to improve oil recovery, the synthesis and functionalization of graphene oxide were studied in order to change the rock's wettability from oil-wet to water-wet conditions [15]. As a tertiary recovery technique, they conducted a number of core flooding studies using nanoparticle fluid. The Amott test was used to evaluate the wettability index using core plugs injected with nanofluid, demonstrating the impact of nanofluid injection on wettability modification [16]. Improving the performance of the traditional water alternating gas process for the oil-wet carbonate reservoirs by implementing a unique technique known as nanofluid alternating gas injection. After conducting several water-alternating gas experimental experiments, carbonate core samples saturated with crude oil were subjected to nanofluid-alternating gas injection [17]. Additionally, the impact of nanofluids on heavy crude oil recovery was examined and contrasted with the traditional waterflooding method [18]. The coordinated impact of aqueous nanofluids on the interfacial characteristics of oil/brine/rock systems and their function in affecting oil displacement from samples of carbonate rock and sandstone were investigated experimentally [19]. Using the micromodel experimental formalism, the pore-scale performance and mechanism of nanofluid for increased oil recovery were examined [20]. In order to ensure accuracy and dependability throughout the research investigation of validating a numerical model to evaluate the efficacy of various nanofluids in enhanced oil recovery applications, the research procedure comprises several crucial stages, starting with the careful selection process used to identify an appropriate base model for validation. concentrating especially on nanoparticles like CuO, SiO2, Al2O3, and TiO. The results show that, under ideal circumstances within the chosen parameter range, the RSM model indicated a theoretical maximum oil recovery of 105% for SiO nanofluid. An average recovery of 78.92% was obtained through validation using saturation testing, which nearly matched the 75% reported in experimental research. This illustrates the model's great potential as a predictive tool for maximizing nanofluid use in actual enhanced oil recovery operations [21]. An anionic surfactant was conjugated to graphene oxide nanosheets by the process of electrostatic forces in research of the innovative generation of nanofluid, which was compared with negatively charged colloidal silica nanoparticle fluid [22]. At the reservoir scale, the impact of hydrophilic nanofluids on oil recovery was measured. doing an internal, real-time investigation through numerical simulations. The findings show that early nanofluid injection provides better oil recovery when nanofluid flooding is utilized as a tertiary recovery approach following waterflooding, but they also show increased nanoparticle loss [23]. Research work that is focused on the mechanism of altering the thermophysical properties of the injected fluid, including its viscosity, by the addition of nanoparticles, and using the FEM method, a model is developed for a 3D numerical simulation. According to the results obtained, an increase in the injection nanofluid flow rate from 0.1 to 0.5 ml/min has had a sensible positive effect on accelerating the enhanced oil recovery process [24]. A new methodology for the interpretation of nanoparticles in enhanced oil recovery processes is being researched. To simulate the change in rock wettability from an oil-wet to a more water-wet state, the workflow employs a dynamic wettability alteration technique.

A finite difference approach is used to solve the model equations numerically. Additionally, the study's conclusions improved knowledge of how well nanoparticles function in both forced and spontaneous enhanced oil recovery procedures [25]. the presence of SiO_2 and Al_2O_2 nanoparticles in a three-dimensional hexagonal prism to improve oil recovery. Numerical modeling in three dimensions is used to study porosity and mass flow rate, nanoparticle concentration, and the impact of relative permeability on oil and water saturation in the presence of gravity under various time durations. The results showed that increasing the oil recovery rate is significantly influenced by the volume percentage of nanoparticles. Additionally, it was noted that the maximum oil recovery occurs at low porosity levels [26]. The effectiveness of co-injecting polymers and nanoparticles in oil reservoirs was examined numerically. The interactions between the two chemical species contributed to the viscoelastic framework to be preserved, which significantly improves operational and production characteristics, according to a set of numerical models of the co-injections of polymer nanoparticles [27]. Both experimental and numerical simulation investigations were used to examine the impact of silicon oxide nanoparticles on the change in wettability of glass micromodels. The computational fluid dynamics (CFD) method was also used to numerically simulate the flooding situations of the experiment in the micromodels. Results showed that there were significant agreements between the simulation and the experiment, and that nanofluid flooding increased the oil recovery process by 13% in CFD techniques and 9% in experimental tests [28]. For improved oil recovery, a novel model for simulating nanofluid injection into a three-dimensional porous medium was examined. to determine, using empirical correlations, how the thermophysical characteristics of nanofluid affect the increased oil recovery process. A time-dependent finite-element approach based on two variables—nanoparticle volume percent and inlet temperature—was used to numerically analyze Darcy's law, mass conservation, concentration, and energy equations. According to their findings, the thermophysical characteristics of the enhanced oil recovery process may be greatly improved by regulating the temperature and nanoparticle volume fraction. Additionally, they found that increasing the volume percentage to 4% and the inlet temperature to 353.15 K improved oil displacement, sweep efficiency, and nanofluid mobility [29].

In this study, an experimental approach is used to investigate nanofluid flooding of carbonated reservoir of both homogenous and heterogeneous porous medium in other to assess the efficiency of periwinkle shell-water based nanofluid in displacing crude oil for secondary and tertiary recovery.

II. MATERIALS AND METHOD

Materials

Shells of periwinkle were collected around a major market area in bonny local government area of Rivers State, Nigeria. The periwinkle shell was washed thoroughly with steam, and then it was dried in an oven, before using distilled water to re-wash the periwinkle shell samples. The dried periwinkle shell samples were crushed using the Hummers method into fine smooth powder form, before it was dried again into a constant weight [30] (Eddy et al, 2024). The NaOH and HCl reagents used in this experimental assessment were purchased from Nzu chemical Ltd, building materials road, mile 3 Port Harcourt, Rivers State, Nigeria. They were put into use directly without further chemical additions.

Preparation of nanofluid

One gram of the dried periwinkle shell nanoparticle was added to 300ml of pure sample of deionized water. Then it was subjected to an ultrasonic wave for 60mins for proper mixing to achieve a uniform sample of periwinkle shell nanoparticle and water.

Fluid

Carbonate reservoir of dark brown crude oil sample of the bonny light with the following physical properties: density of 0.850g/cm3 and a viscosity of 15.41cp with an API of 32.9 - 37.0, specific gravity of 0.8397–0.8498 at 15^{o}C. Three samples of nanofluid with varying nanoparticle concentrations of 250ppm, 450ppm and 650ppm was prepared using the ultrasonic bath for a controlled stability of nanofluid of 30hrs. The zeta potential of the nanofluid sample was left at a value of 27^{o}C. The nanofluid pH performance based on stability was ascertained using the zetasizer Nano-Z

III. RESULTS AND DISCUSSION

For the purpose of comparison, the same tests were conducted using water and an aqueous solution of anionic surfactant as a working agent. Test results are shown on Table 1.

Table 1: Oil flow rate

Fluid agent			
	Additives	Concentration	Oil flow rate
Water	Water	100	0.025
Aqueous solution of surfactant	Surfactant	0.06	0.059
Nanofluid	Nanoparticle	0.0010	0.081
		0.0015	0.084
		0.0020	0.086

The nanofluid then displaced the crude oil. When compared to the anionic surface-acting agent's aqueous solution, the production rate of oil displaced by the nanofluid is much higher and more than four times higher when compared to water. The viscosity of water plus surfactant aqueous solution is double that of the smallest nanofluid Newtonian viscosity. It is clear that improved pore wettability and decreased interfacial tension on the nanofluid–oil interface result in an energy reduction of oil in relation to the porous medium surface, which raises the oil flow rate.

The mean permeability of the heterogeneous porous media was set to match that of the homogeneous medium in order to compare the outcomes. At a temperature of 25°C and a pressure drop of 0.1 MPa, displacement was performed. For that set of studies, we employed three distinct displacement agents: water, a surfactant aqueous solution (0.05% mass sodium dodecyl sulfate solution) and nanofluid (0.05% mass sodium dodecyl sulfate solution), and 0.001% mass nanoparticles. Table 2 displays the oil recovery data, which were recorded based on the injected fluid's pore volume.

Table 2: Free and finite factor of flooding fluid

Oil Recovery				
Displacement agent	Homogenous medium		Heterogeneous medium	
	Water-free oil recovery (%)	Finite oil recovery (%)	Water-free oil recovery (%)	Finite oil recovery (%)
Water	31.00	51.02	28.41	46.85
Aqueous solution	37.00	52.84	23.29	46.59
Nanofluid	52.00	59.32	45.06	57.06
Nanofluid slug			45.06	57.09

Using nanofluid, oil recovery in a homogenous porous medium at water-free conditions was increased to roughly 51% and 35%, respectively, depending on the water and acidic solution. When compared to water and surfactant solution, the increase in finite oil recovery was 17% and 12%, respectively. Nanofluid as a displacement agent boosted oil recovery in a heterogeneous porous medium at water-free oil recovery by more than 66% when compared to water; however, the increase in oil recovery was only 17% and 22% when compared to surfactant solution and water, respectively. It should be mentioned that water-free and finite oil recovery at oil recovery by nano-fluid slug, which is observed to be 20% from pore volume, are the same as comparable parameters at constant recovery by nanofluid.

The drop shape analysis method at 298 K yields the wetting angle and the interfacial tensions of the aqueous solution–oil contact. The outcomes are displayed in Table 3. The table illustrates how adding nanofluid essentially has no effect on oil wettability.

Table 3: Oil Wettability

Concentration (% mass)		
Oil	Nanofluid	Wettability
100	0	0.77
100	0	0.92
100	0.001	0.95

A drop shape tensiometer DSA30 was used to measure all stated interfacial tension values.

Additionally, observation showed that the presence of nanoparticles at the interfacial layers results in a decrease in interfacial tension.

Table 4: Surface tension

Concentration (*% mass*)	Surface Tension ($10^{-5}N/m$)
0.001	9.26
0.001	5.53
0.001	3.69
0.001	1.84
0.001	1.15

When the concentration of nanoparticles is reduced, they adhere to the liquid's surface and reduce surface tension as a result of the absorption process. Using 0.004–0.0078% mass of sodium dodecyl sulfate solution, nanoparticles reduce surface tension by 70

IV. CONCLUSION

When utilizing 0.004–0.0078% mass of sodium dodecyl sulfate solution, nanoparticles reduce surface tension; however, this effect diminishes when the concentration of sodium dodecyl sulfate exceeds 0.0156% mass. Surface tension is reduced by nanoparticles adhered to the liquid's surface as a result of absorption. Additionally, depending on the water and surfactant solution, water-free oil recovery increased by 51% and 35% in homogenous pore media and was finite by 17% and 12%. Water-free oil recovery in a heterogeneous pore medium increased by 66% when compared to water and it was finite by about 20% and 16% when compared to water and surfactant solution. It should be mentioned that water-free and finite oil recovery at oil recovery by nano-fluid slug are the same as comparable parameters for constant recovery by nanofluid. The efficiency of the oil displacement flow rate was significantly increased by applying the nanosuspension created here. When compared to the aqueous solution of anionic surface-acting agent, the production rate of oil displaced by the nanofluid is over one-and-half times higher, and when compared to water, it is above four times higher.

V. ACKNOWLEDGEMENT

This research work is a proceed of the Institutional Base Research (IBR) of the tertiary education trust fund (refund). I also wish to acknowledge the effort of the management of Federal Polytechnic of Oil and Gas Bonny for the effort in securing the grant.

REFERENCES

[1] Wei, B., Li, Q., Jin, F., Li, H., & Wang, C. (2016). The potential of a novel nanofluid in enhancing oil recovery. *Energy & Fuels*, *30*(4), 2882-2891.

[2] Zhang, H., Ramakrishnan, T. S., Nikolov, A., & Wasan, D. (2016). Enhanced oil recovery driven by nanofilm structural disjoining pressure: flooding experiments and microvisualization. *Energy & Fuels*, *30*(4), 2771-2779.

[3] Tajik, S., Shahrabadi, A., Rashidi, A., Jalilian, M., & Yadegari, A. (2018). Application of functionalized silica-graphene nanohybrid for the enhanced oil recovery performance. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, *556*, 253-265.

[4] Nowrouzi, I., Mohammadi, A. H., & Manshad, A. K. (2020). Primary evaluation of a synthesized surfactant from waste chicken fat as a renewable source for chemical slug injection into carbonate oil reservoirs. *Journal of Molecular Liquids*, *306*, 112843.

[5] Gbadamosi, A., Junin, R., Manan, M., Agi, A., & Oseh, J. (2019). *Nanotechnology application in chemical enhanced oil recovery: current opinion and recent advances*. IntechOpen.

[6] Zamani, H., Jafari, A., Mousavi, S. M., & Darezereshki, E. (2020). Biosynthesis of silica nanoparticle using Saccharomyces cervisiae and its application on enhanced oil recovery. *Journal of Petroleum Science and Engineering*, *190*, 107002.

[7] Ali, J. A., Kolo, K., Manshad, A. K., & Mohammadi, A. H. (2018). Recent advances in application of nanotechnology in chemical enhanced oil recovery: Effects of nanoparticles on wettability alteration, interfacial tension reduction, and flooding. *Egyptian journal of petroleum*, *27*(4), 1371-1383.

[8] Sagala, F., Montoya, T., Hethnawi, A., Vitale, G., & Nassar, N. N. (2019). Nanopyroxene-based nanofluids for enhanced oil recovery in sandstone cores at reservoir temperature. *Energy & fuels*, *33*(2), 877-890.

[9] Khoshkar, P. A., Fatemi, M., & Ghazanfari, M. H. (2020). Static and dynamic evaluation of the effect of nanomaterials on the performance of a novel synthesized PPG for water shut-off and improved oil recovery in fractured reservoirs. *Journal of Petroleum Science and Engineering*, *189*, 107019.

[10] Yang, C., & Leong, K. (2002). Influences of substrate wettability and liquid viscosity on isothermal spreading of liquid droplets on solid surfaces. *Experiments in fluids*, *33*(5), 728-731.

[11] Jesionowski, T., & Krysztafkiewicz, A. (2002). Preparation of the hydrophilic/hydrophobic silica particles. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, *207*(1-3), 49-58.

[12] [12] Adil, M., Lee, K., Mohd Zaid, H., Ahmad Latiff, N. R., & Alnarabiji, M. S. (2018). Experimental study on electromagnetic-assisted ZnO nanofluid flooding for enhanced oil recovery (EOR). *PloS one*, *13*(2), e0193518.

[13] Li, S. (2016). An experimental investigation of enhanced oil recovery mechanisms in nanofluid injection process.

[14] Li, R., Jiang, P., Gao, C., Huang, F., Xu, R., & Chen, X. (2017). Experimental investigation of silica-based nanofluid enhanced oil recovery: the effect of wettability alteration. *Energy & Fuels*, *31*(1), 188-197.

[15] Jafarbeigi, E., Kamari, E., Salimi, F., & Mohammadidoust, A. (2020). Experimental study of the effects of a novel nanoparticle on enhanced oil recovery in carbonate porous media. *Journal of Petroleum science and Engineering*, *195*, 107602.

[16] Li, S., Genys, M., Wang, K., & Torsæter, O. (2015, September). Experimental study of wettability alteration during nanofluid enhanced oil recovery process and its effect on oil recovery. In *SPE Reservoir Characterisation and Simulation Conference and Exhibition* (p. D031S020R003). SPE.

[17] Moradi, B., Pourafshary, P., Jalali, F., Mohammadi, M., & Emadi, M. A. (2015). Experimental study of water-based nanofluid alternating gas injection as a novel enhanced oil-recovery method in oil-wet carbonate reservoirs. *Journal of Natural Gas Science and Engineering*, *27*, 64-73.

[18] Alomair, O. A., Matar, K. M., & Alsaeed, Y. H. (2015). Experimental study of enhanced-heavy-oil recovery in Berea sandstone cores by use of nanofluids applications. *SPE Reservoir Evaluation & Engineering*, *18*(03), 387-399.

[19] Kuang, W., Saraji, S., & Piri, M. (2018). A systematic experimental investigation on the synergistic effects of aqueous nanofluids on interfacial properties and their implications for enhanced oil recovery. *Fuel*, *220*, 849-870.

[20] Li, R., Jiang, P., Gao, C., Huang, F., Xu, R., & Chen, X. (2017). Experimental investigation of silica-based nanofluid enhanced oil recovery: the effect of wettability alteration. *Energy & Fuels*, *31*(1), 188-197.

[21] Priya, K., & Oumer, A. N. (2025). Numerical Analysis of Enhanced Oil Recovery using Nanofluids. *International Journal of Automotive and Mechanical Engineering*, *22*(3), 12725-12747.

[22] Khoramian, R., Kharrat, R., & Golshokooh, S. (2022). The development of novel nanofluid for enhanced oil recovery application. *Fuel*, *311*, 122558.

[23] Feng, Y., Cao, L., & Shi, E. (2017). A numerical investigation of enhanced oil recovery using hydrophilic nanofluids. *Journal of Sustainable Energy Engineering*, *5*(1), 67-97.

[24] Esfe, M. H., & Esfandeh, S. (2020). 3D numerical simulation of the enhanced oil recovery process using nanoscale colloidal solution flooding. *Journal of Molecular Liquids*, *301*, 112094.

[25] Khosravi, R., Chahardowli, M., Keykhosravi, A., & Simjoo, M. (2021). A model for interpretation of nanoparticle-assisted oil recovery: Numerical study of nanoparticle-enhanced spontaneous imbibition experiments. *Fuel*, *292*, 120174.

[26] Zafar, M., Sakidin, H., Sheremet, M., Dzulkarnain, I., Nazar, R., Al-Yaari, A., ... & Bashir, S. (2023). A numerical investigation of mathematical modelling in 3D hexagonal porous prism on oil recovery using nanoflooding. *Heliyon*, *9*(8).

[27] Loaiza, C. S., Patiño, J. F., & Mejía, J. M. (2020). Numerical evaluation of a combined chemical enhanced oil recovery process with polymer and nanoparticles based on experimental observations. *Journal of Petroleum Science and Engineering*, *191*, 107166.

[28] Rostami, P., Sharifi, M., Aminshahidy, B., & Fahimpour, J. (2019). The effect of nanoparticles on wettability alteration for enhanced oil recovery: micromodel experimental studies and CFD simulation. *Petroleum Science*, *16*(4), 859-873.

[29] Al-Yaari, A., Ling Chuan Ching, D., Sakidin, H., Sundaram Muthuvalu, M., Zafar, M., Haruna, A., ... & Azad, A. S. (2023). A new 3D mathematical model for simulating nanofluid flooding in a porous medium for enhanced oil recovery. *Materials*, *16*(15), 5414.

[30] Eddy, N. O., Oladede, J., Eze, I. S., Garg, R., Garg, R., & Paktin, H. (2024). Synthesis and characterization of CaO nanoparticles from periwinkle shells for the treatment of tetracycline-contaminated water by adsorption and photocatalyzed degradation. *Results in Engineering*, *24*, 103374.