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A Review on Waterflooding Problems in Nigeria's Crude Oil Production

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For many reasons, a reservoir may approach the end of its primary life having recovered only a small fraction of the oil in place. Occurrence of this makes secondary recovery operations feasible and economically attractive through waterflooding. Waterflooding is dominant among fluid injection methods and is responsible for the current high level of production rate of crude oil. Nigeria's current average crude oil production is estimated at 2.2 million barrel per day and its' reserve at 38.4 billion barrels. The problems associated with waterflooding and oil production are formation damage, scale deposition and corrosion of well tubular. These problems are costing the oil industries a huge loss annually, this article suggests control and monitoring of these problem through modeling and simulation of oil reservoirs in Nigeria oil fields.

Keywords Waterflooding, crude oil, formation damage, scale formation, corrosion, reservoir, OOIP

INTRODUCTION

The conventional crude oil recovery mechanism globally is divided into primary, secondary and tertiary (Figure 1). The primary recovery method start the life of any recovery from a dug oil reservoir in which through the natural energy and high pressure embedded in the ground the oil is pushed to the surface. Continuous process of recovery eventually lead to a depletion in the pressure and energy in the oil bearing formation which make secondary recovery important in recovering more of the Original Oil In Place (OOIP) of a given reservoir. Tertiary oil recovery reduces the oil's viscosity to increase oil production. Tertiary recovery is started when secondary oil recovery techniques are no longer enough to sustain production or when there is heavy crude oil component.

The most popular type of secondary recovery is the waterflooding process (Figure 2). Waterflooding is dominant among fluid injection methods and is without question responsible for the current high level of production rate and reserves. It popularity is accounted for by:

1. the general availability of water,
2. the relative ease with which water is injected, owing to the hydraulic head it possesses in the injection well,
3. the ability with which water spreads through an oil-bearing formation,
4. and water efficiency in displacing oil.

It is generally acknowledged that the first waterflood occurred as a result of accidental water injection in the Pithole City area of Pennsylvania in 1865.[1] In 1880, Carll concluded that water, finding its way into a well bore from shallow sands, would move through oil sands and be beneficial in increasing oil recovery. Many of the early waterfloods occurred accidentally by leaks from shallow water sands or by surface water accumulations entering drilled holes. At that time it was felt that the main function of water injection was to maintain reservoir pressure, allowing wells to have a longer productive life than pressure depletion.[1–4]

WATERFLOOD PROBLEMS IN OIL RESERVOIRS

The exploration and production of crude oil by waterflood process involves injecting water through an injector well to produce oil from the producer well as demonstrated in Figure 2. Crude oil production could lead to some undesirable problems. Some of these problems are formation damage, scale deposition and corrosion within the well tubular conveying the crude to the storage unit. These problems lead to a noneconomical operation and a reduction in oil production for the oil

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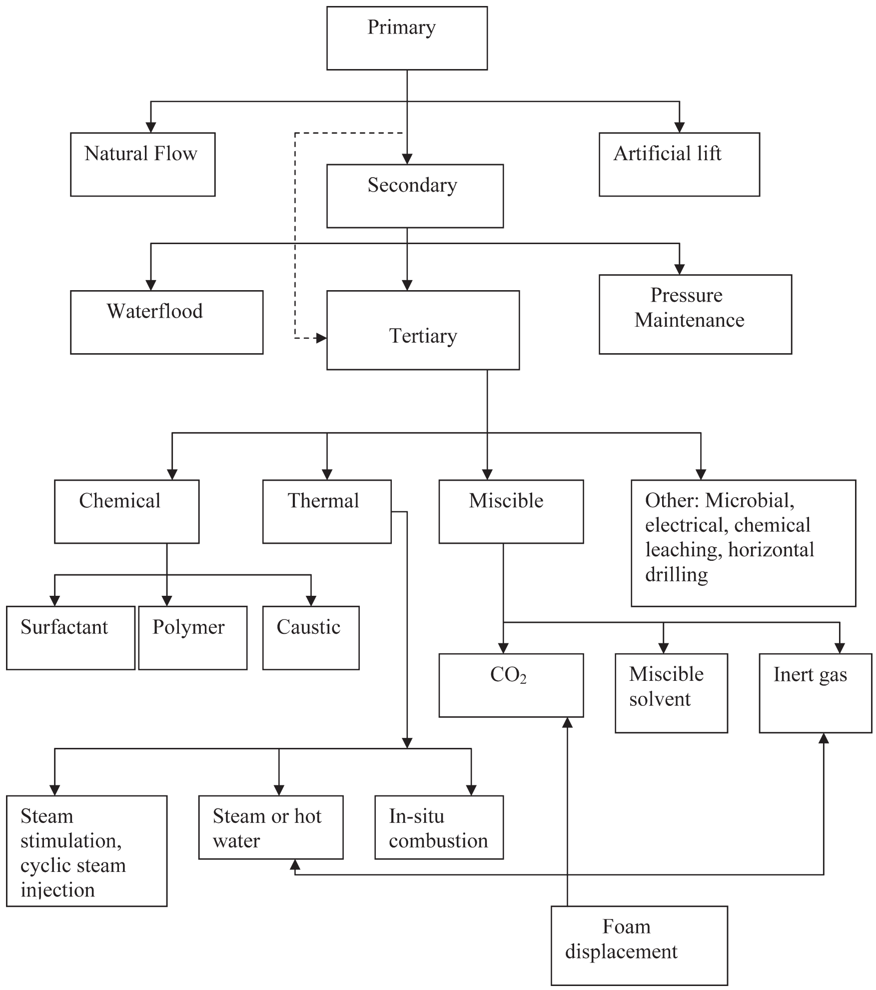

FIG. 1. Conventional oil recovery mechanism.[4]

industries; it is costing the oil industries millions of dollar annually and is a major headache to the industry.

FORMATION DAMAGE

Formation damage is a generic terminology referring to the impairment of the permeability of petroleum bearing formations by various adverse processes. Formation damage is an undesirable operational and economic problem that can occur during the various phases of oil and gas recovery from subsurface reservoirs including production, drilling, hydraulic fracturing and work over operations. Properly designed experimental analytical techniques and the modeling and simulation approach can help in understanding, diagnosis, evaluation, prevention, remediation and controlling of formation damage in oil and gas reservoirs.[5]

Amaefule et al.[6] listed the conditions affecting formation damage in four groups: (1) type, morphology, and location of resident minerals; (2) in situ and extraneous fluids composition; (3) in situ temperature and stress conditions and properties of porous formation, and (4) well development and reservoir exploitation practices. Work by Bennion[7] gives the common formation damage mechanism. Bishop[8] also gave a summary of this mechanism by Bennion and Thomas[9] as:

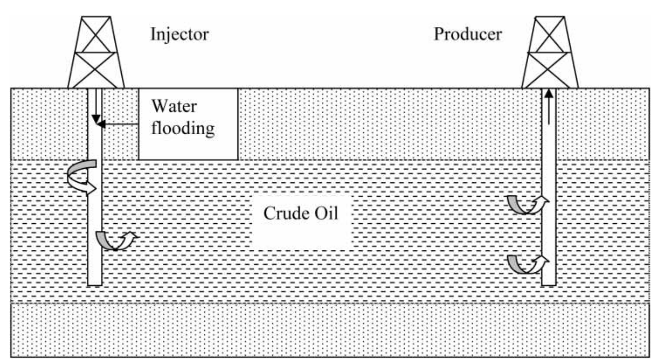

FIG. 2. Waterflooding process showing injector and producer wells.

1. Fluid-fluid incompatibilities generated between invading oil based mud filtrate and formation water.
2. Rock-fluid incompatibility between potentially swelling smectite clay by nonequilibrium water based fluid.
3. Solid invasion of drilled solids.
4. Phase trapping caused by the invasion and entrapment of water based fluids in the near well bore region of gas reservoir.
5. Chemical wettability alteration caused by emulsifier adsorption changing the wettability and fluid flow properties of a formation.
6. Fine migration of fine particles within a rock's pore structure resulting in the plugging of pore throats.
7. Biological activities caused by introduction of bacterial agents into the formation during drilling and the generation of polymer slimes which reduces permeability.

SCALE DEPOSITION

Scale is a deposit of the inorganic mineral components of water. This is in contrast with wax and asphaltenes which deposit from the crude oil. Oilfield scale is generally inorganic salts such as carbonates and sulfates of the metals calcium, strontium and barium. Scale may also be the complex salts of iron such as sulfides, hydrous oxides and carbonates. The major forms of oilfield scale can form in one of two ways:

1. As brine (e.g., formation water) undergoes a temperature or pressure change during production, the solubility of some of the inorganic constituents will decrease and result in the salts precipitating. Scales formed under these conditions are generally calcium/magnesium carbonate scales.
2. When two incompatible waters (such as formation water rich in calcium, strontium and barium and sea water rich in sulfate) are mixed. Scales formed under these conditions are generally sulfate scales.

Other minor forms of scale are also possible:

1. Iron scales which are usually a result of corrosion in the system. The source of the iron is predominately the pipe work and vessels.
2. Halite (NaCl) can occur as a result of water flash-off into the gas phase as the pressure decreases or simply due to reduced halite solubility as the temperatures declines during production of very high salinity brines.
3. Witherite ($BaCO_3$) and others such as calcium fluoride (CaF_2) have been observed in high pressure/high temperature reservoirs.

There is one other additional problem. During normal scale deposition (typically $BaSO_4$), naturally occurring, radioactive isotopes can become tied up in the scale deposit. This result in deposits called Naturally Occurring Radioactive Material (NORM) which is a highly regulated, hazardous substance. In this case, prevention of the normal scale deposit is the easiest and cheapest way to prevent the formation of NORM.[10]

SCALE FORMATION DURING WATERFLOODING

Scale problems may be encountered when new water injection wells are commissioned if the injection water is intrinsically incompatible with the formation water. For example, sea water injection into an aquifer rich in strontium and/or barium ions could cause problems (Figure 3). Two potential problems could arise:

1. The act of lifting and treating injection water can cause problems as the injection water itself can become unstable. This can be a rather serious problem because the problem will be continuous.
2. Injecting a water which is itself stable (but intrinsically incompatible with the aquifer) into a new injector can also cause scale formation. In this case, the potential problem will diminish once the well has been thoroughly flushed with injection water.

CORROSION AND PETROLEUM FLUID

Oilfield corrosion process that most adversely affects the economics of production, transportation, and refining are mainly those that involve the destruction of iron. The low cost, ease of equipment fabrication, structural strength, and availability of mild steels are interstitial alloys of iron containing small amount of carbon and other atoms. High-carbon steel consists of 0.75–1.5% carbon, situated in the octahedral holes of the iron lattice. Some of the other impurities that produce electrolytic cells, thereby enhancing the potential for corrosion, are displaced by the incorporation of carbon into the iron. The smelting of iron ore are almost always results in the inclusion of several other metals that are found in close association with

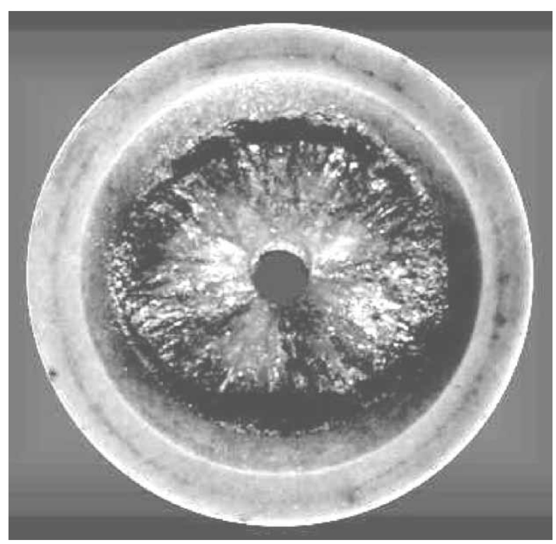

FIG. 3. Scale deposition during crude oil production.[10]

iron. Thus, the impurities in the metallic iron remain throughout the fabrication process, unless special purification steps are taken or displacement by agents such as carbon is performed. Obviously, purification methods involve costs that are, except in rare cases, in excess of those the petroleum companies are willing to pay.[11]

THE NIGERIA SCENARIO

Crude oil production is about 50 years old in Nigeria. Although oil exploration began in Nigeria in 1938, when Shell d'Arcy (later Shell BP) obtained a license, it was not until June 1956, that the company discovered oil in commercial quantity at Oloibiri (in present Bayelsa State). Export of crude oil started in 1958, today there are, in the Niger Delta, 11 oil companies operating 159 oil fields and 1481 wells. In recent publication by the African Development Bank (ADB), Nigeria's total earnings from crude oil was put at $600 billion (about N 84 trillion) in the past 45 years, which translate into N 1.8 trillion per annum for 45 years.[12]

Nigeria is one of the top 10 oil producing countries in the world with a current crude oil production of 2.2 million barrel per day. Its crude oil reserve is estimated at 38.4 billion barrels of crude oil. At the current production rate it is estimated that the oil reserve would be exhausted in the next 38 years. This leaves the country with no other option than to get as much oil as it could get from its oil reservoir, meaning going beyond the matured stage of its oil well to secondary production and enhanced tertiary production stages.[2]

The secondary and tertiary production stage involves the use of waterflooding matured oil well, in some oil wells this is already proving its worth but it comes with the associated problems mentioned above. In the near future there will be a need to apply the method of modeling and simulation approach for understanding, diagnosis, evaluation, prevention, remediation, and controlling the problem of formation damage, scale deposition and corrosion potentials which occurs during production from the Nigeria oil wells.

CONCLUSION

When a reservoir reaches the end of its primary life having recovered only a small fraction of the oil in place, it becomes necessary to apply the improved oil recovery method of waterflooding to achieve economical operations. Waterflooding is dominant among fluid injection methods and is responsible for the current high level of production rate of crude oil. The waterflooding process comes with its own inherent problems, such as formation damage, scale deposition and corrosion of well tubular. These problems are costing the oil industries a huge loss annually. This article suggests the application of a predictive means of modeling and simulation as a possible means of evaluating and controlling these problems.

REFERENCES

[1] API. (1961) *History of Petroleum Engineering*; API: Dallas, TX.

[2] Adeniyi, O.D. (2006) An introduction to analysis and model development for improved oil recovery (IOR) by the waterflooding process Ph.D Seminar I Presentation University of Lagos: Lagos, Nigeria, 19 July, pp. 2–29.

[3] Carll, J.F. (1880) The geology of the oil regions of Warren, Venango, Clarion and Butler Counties, Pennsylvania; Second Geological Survey of Pennsylvania (1880) III, 1875–1880.

[4] Lake, L.W., Schmidt, R.L., and Venuto, P.B. (1992) *Petr. Eng. Int.*, 55–61.

[5] Civan, F. (2000) *Reservoir Formation Damage—Fundamentals, Modeling, Assessment and Mitigation*; Gulf Publishing Co.: Houston.

[6] Amaefule, J.O., Kersey, D.G., Norman, D.L., and Shannon, P.M. (1988) Advances in Formation damage Assessment and Control Strategies. CIM Paper No. 88-39-65, Proceedings of the 39th Annual Technical Meeting of Petroleum Society of CIM and Canadian Gas Processors Association, Calgary, Alberta, June 12–16.

[7] Bennion, B. (1999) *J. Can. Pet. Technol.*, 38 (2): 11–17.

[8] Bishop, S.R. (1997) Experimental Investigation of Formation Damage Due to the Induced Flocculation of Clays Within a Sandstone Pore Structure by High Salinity Brine, SPE 38156 paper, presented at the 1997 SPE European Formation damage Conference, The Hague, The Netherlands, June 2–3; pp.123–143.

[9] Bennion, D.B. and Thomas, F.B. (1994) "Understanding Drilling of Horizontal wells: Does it Really Eliminate Formation Damage?", SPE 27352 paper, SPF Formation Control Symposium, Lafayette, Louisiana, February.

[10] Niesen, V. "*Deepstar III Project*," Multiphase Solutions, Inc. 2015 N. Ash, Suite #4 Ponca City, OK 74601.

[11] Becker, J.R. (1998) *Corrosion and Scale Handbook*; PennWell Publishing Company: Tulsa, Oklahoma.

[12] Guardian Newspaper, Oil-50 years on, Nigerian Guardian Newspapers Limited: Oshodi Lagos, Nigeria, June 13, 2006, p. 16.

[13] Bennion, D.B., Thomas, F.B., and Bennion, D.W. (1991) "Effective Laboratory Coreflood Tests to Evaluate and Minimize Formation Damage in Horizontal Wells," presented at the Third International Conference on Horizontal Well Technology, Houston, Texas, November.