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# Enhanced Oil Recovery Practices: Global Trend, Nigeria's Present Status, Prospects and Challenges

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***Authors' contributions***

*This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.*

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## ABSTRACT

Enhanced oil recovery (EOR) techniques are considered due to unimpressive oil recovery, limited oil reserves, and non-applicability of primary recovery methods in some (heavy oil) fields. In Nigeria, preparation is in gear towards implementing EOR projects. This paper therefore reviews the global trend of EOR practices and discusses Nigeria's present status, prospects, and challenges.

Most EOR projects are employed in sandstone (high permeability) reservoirs; hence based on lithological considerations, all EOR methods are feasible in Nigeria. However, miscible hydrocarbon gas injection is found to be a very good EOR choice because it would drastically reduce the uneconomical practice of gas flaring; besides, transportation of carbon dioxide ($CO_2$) and flue gas is virtually non-existent in Nigeria. Chemical (especially surfactant) flooding is costly; hence it would be feasible in Nigeria if oil price is high. At present, cost implications of heat treatment facilities may be an impedance to implementing thermal EOR for heavy oil in Nigeria. Though microbial EOR is the cheapest, it is not favorable in high temperature (above 85 $^oC$), high salinity (above 100,000 ppm) and deeper (beyond 3,500m) reservoirs.

For EOR practices to thrive in Nigeria, there should be an extensive economic evaluation and forecasting, effective research and development, effective training of technical staff for proper operation, surveillance and maintenance of EOR projects, implementation of health, safety and

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environmental (HSE) guidelines, low inflation rates, low interest rates on loans, general price stability, favorable tax policy, low import duties on machineries and equipment used for EOR, modified private market decisions and encouraging legal and regulatory framework.

*Keywords: Enhanced oil recovery global trend; prospects; challenges.*

## 1. INTRODUCTION

In primary recovery, hydrocarbons are produced through natural reservoir drives that cause fluid flow into the wellbore and the surface. During primary recovery, typically only 5 to 15 percent of initial hydrocarbons are produced. After primary recovery, the use of water flooding and/or immiscible hydrocarbon (HC) injection for fluid displacement, and the use of water injection for pressure maintenance is termed secondary recovery. The schematic of water flooding is shown in Fig. 1.

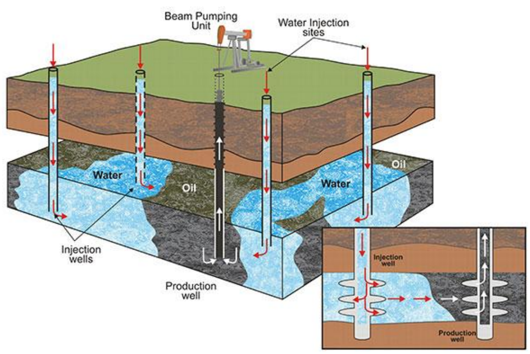


**Fig. 1. Schematic of water flooding**
*(Source: [1;2;3])*

However, about one third of the Original Oil Initially in Place (OOIIP) can only be recovered through traditional primary and secondary recovery methods [4]. Hence, the attention of the oil industry had been directed to EOR techniques for more production from the existing oil fields because of the unimpressive oil recovery, limited oil reserves and oil price increase. EOR methods could be classified as gas injection, chemical flooding, nanofuid flooding, thermal processes and microbial EOR.

Not all types of gas injection are classified as EOR, and the definitions are not always precise. According to Verdier [5], the following gas injection modes are clearly classified as EOR: (i) all injections of non-hydrocarbon gas (nitrogen, $CO_2$ and flue gas), (ii) injections of miscible or partially miscible hydrocarbon gas, (iii) water-alternating-gas (WAG) and simultaneous water and gas (SWAG) injections (whatever the gas may be). The schematic of WAG injection is shown in Fig. 2.

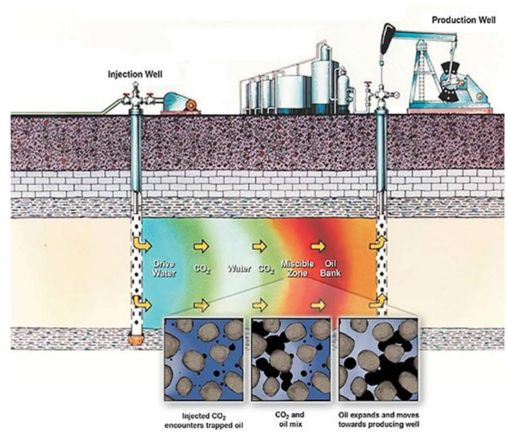


**Fig. 2. Schematic of $CO_2$ water-alternating-gas injection**
*(Source: [6])*

Chemical flooding includes alkaline flooding, surfactant flooding, polymer flooding, surfactant-polymer (SP) flooding, and alkali-surfactant-polymer (ASP) flooding [7]. The schematic of surfactant flooding is shown in Fig. 3.

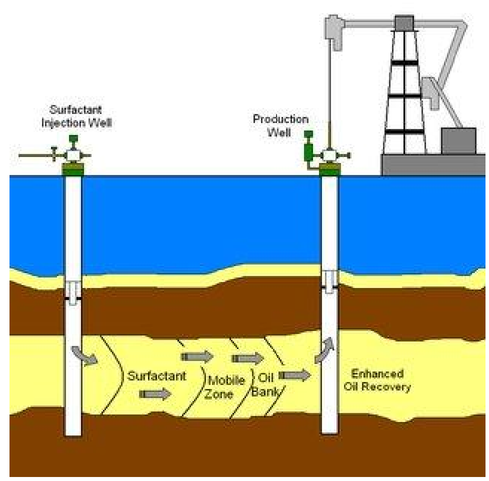


**Fig. 3. Schematic of surfactant flooding**
*(Source: [6])*

Thermal processes include in-situ combustion (ISC) or high pressure hot air injection (HPAI), steam/hot water injection, toe-to-heal air injection (THAI) and steam assisted gravity drainage (SAGD). The schematic of SAGD is shown in Fig. 4.

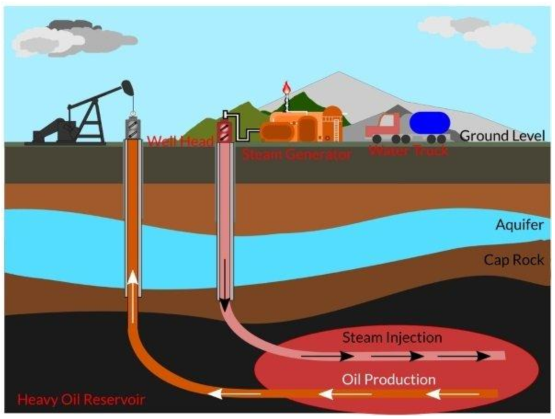


**Fig. 3. Schematic of steam assisted gravity drainage (SAGD)**
*(Source: [8])*

Some benefits of EOR are absence of exploration cost and risk, utilization of existing infrastructure, available reservoir geological and engineering data, improved mobility ratio, and substantial economic growth through increase in oil production and job creation.

Improved oil recovery (IOR) methods encompass EOR methods as well as new drilling and well technologies, intelligent reservoir management and control, advanced reservoir monitoring techniques and the application of different enhancements of primary and secondary recovery processes [9].

The sale of oil and gas accounts for about 95% of Nigeria's foreign exchange earnings. There are four basins in Nigeria where oil prospecting has been carried out, namely; Niger Delta (major basin), Chad (minor basin), Gombe/Bauchi and Anambra basins. The Niger Delta Basin is one of the largest in the world and it is made up of Benin, Agbada and Akata formations [10].

A large number of producing field in Nigeria are entering the mature stage for primary and/or secondary depletion. In Nigeria, at present, some companies have already embarked on secondary recovery schemes, precisely water flooding. And preparation is in gear towards implementing EOR based on findings from EOR simulations and laboratory core flooding.

Hence, this paper reviews the global trend of EOR practices and Nigeria's present EOR status, and discusses the prospects, and the technical, financial, legal and environmental challenges of EOR in Nigeria.

## 2. METHODOLOGY

### 2.1 Review of Global Trend of EOR Projects

In the past, oil companies often avoided using EOR due to technological challenges, cloudy regulations, and costly implementation. However, new technologies, increased availability of required materials and the rising government interest and investment have made EOR to quickly become more feasible. EOR is expected to perform very well in the global supply of petroleum-based energy [11,12].

The world total oil production at present is around 84 million bpd; out of this, EOR projects account for about 1,627,000 bpd (i.e. about 2%). In 2009, more than half of the global EOR production was from the United States, Canada, and China combined. Out of 316 global EOR projects recorded in 2010, the United States has 193 projects; Canada has 40 projects while 83 projects are in the rest of the world [13,14]. However, by 2015, the big three producers from 2009 are forecast to hold only a third of the EOR market share as more governments around the world begin to compete with a view to maximizing the ability of their respective country to increase oil revenue through increased production and reduce demand for oil imports in the process [12].

Many of the global EOR projects highlighted in this paper are sourced from the updated review done by Alvarado and Manrique [9].

**Review of Gas Injection:** Gas injection has been the most widely employed EOR technique for light, condensate and volatile oil reservoirs. Immiscible nitrogen floods are employed in Hawkins field, Texas and Elk Hills, California, both in the United States [15]. There are HC gas injection projects in Canada and the U.S. apart from the North Slope of Alaska. The North Slope of Alaska hosts most of immiscible and miscible HC gas injection projects in the U.S. [15-19]

while a miscible gas injection project is in Brassey Field, Canada [15].

$CO_2$ gas injection, however, has been the most widely used EOR process for medium and light oil production in sandstone reservoirs during last decades, mainly in the U.S. due to the accessibility to cheap and readily available $CO_2$ from natural sources. Cranfield Field, Heidelberg West and Lazy Creek Field in Mississippi and Sussex Field in Wyoming are some examples of planned $CO_2$-EOR projects in the U.S. [15]. Wyoming sandstone reservoirs are also expected to commence more $CO_2$-EOR projects [20]. In Brazil, $CO_2$ floods are executed in Buracica and Rio Pojuca fields ([15] and [21]) and a $CO_2$ gas injection in Miranga field as an EOR and carbon sequestration strategy had been reported ([21,22]). Also, Canada employs $CO_2$ gas EOR in Joffre and Pembina fields [15,23]; while a $CO_2$ pilot injection is in Croatia at Ivanić field. Hungary also carried out $CO_2$ gas injection for more than four decades at Budafa and Lovvaszi fields [24]; while a more recent $CO_2$ gas injection is reported at Szank [25]. Trinidad also has been operating $CO_2$ gas injection projects for more than three decades; $CO_2$ is sourced from an ammonia plant near the fields [26]. Few examples of countries evaluating $CO_2$ sources and EOR potential in mature fields are Mexico [26] and the U.S. [20,27].

Gas injection was reported to enhance recovery of oil from Bakken shale formation [28-31].

**Review of Chemical Flooding:** Chemical EOR methods, particularly polymer flooding, thrived well in the 1980's, most of them in sandstone reservoirs [32]. However, global oil production from chemical EOR processes has been insignificant since 1990's, except for China [33-36]. Pilots or large-scale polymer floods were done in North Burbank field in Oklahoma, United States, Pelican Lake field in Canada, Daqing, Gudao, Gudong and Karamay fields in China, El Tordillo field in Argentina, and Jhalora field in India among others [15]. Other reported polymer flooding projects include Carmópolis, Buracica and Canto do Amaro fields in Brazil ([37], Sanand field in India [38,39], Marmul field in Oman [15,40]. In addition, Argentina, Brazil, Canada and Germany announced plans to commence polymer flood projects in Argentina El Tordillo field, Voador offshore field, Horsefly Lake field and Bochstedt field respectively [15]. However, one of the largest ASP flood projects as of today is in Daqing Field where ASP flooding has been studied and tested through several pilots of different scales for over 15 years [36,41-44]. Other Chinese ASP projects documented in the literature are Gudong [45], Karamay [46,47], Liahoe and Shengli [36] fields.

Experimental investigation of oil displacement with ionic liquids shows its potential of enhancing oil recovery [48].

**Review of Nanofluid Flooding:** Nanofluid is a colloidal mixture consisting of nanoparticles dispersed in a fluid medium to improve desired properties of the fluid. Nanoparticles can move freely through the liquid molecules by following a random path governed with Brownian motion. Stability of nanoparticles in colloidal mixture are affected by their nano-size and larger surface area per unit weight. Other important factors affecting nanoparticles stability in colloidal mixtures are van der Waals forces and the surface charges of the nanoparticles. The stability of nanofluid is determined by the sum of the attractive (and repulsive) van der Waals forces between the particles [49]. Nanofluid stability is sustained and nanoparticles aggregation is avoided if the nanoparticle repulsive forces exceed the attractive forces [50]. This could be achieved by altering charge density and zeta potential of the nanoparticles [51].

Nanoparticles are comparatively cheaper than chemicals and are employed in oil recovery because of their ability in altering in-situ conditions responsible for sustenance of residual oil in the reservoir. Nanoparticles have ability to migrate through pore throats and travel a long distance in porous media to yield excellent microscopic oil displacement [52-57]. Nanoparticles have been reported to reduce interfacial tension (IFT) and alter wettability [58]. Since nanoparticles inclusion relatively increases the viscosity of displacing fluid, it is certain that mobility ratio would be reduced. The synergy of IFT reduction, wettability alteration and displacing fluid viscosity increase leads to an increase in capillary number (the ratio of viscous to capillary forces) and this assists in overcoming capillary pressure especially at the pore throats.

Laboratory reports show that nanofluids increases oil recovery; the degree of increase depends on the properties of the nanofluids such as nanoparticles size, concentration and material types, and the type of fluid [59-66]. Nanoparticles in water-based nanofluid alter the wettability of the reservoir from oil-wet to water-wet [67].

Enhanced oil recovery using nanofluids had been reviewed extensively. The reviewers include Ayatollahi and Zerafat [58], Friedheim et al. [68], Bennetzen and Mogensen [69], ShamsiJazeyi et al. [70], Negin et al. [71], Cheraghian and Hendraningrat [72,73], Idogun et al. [74], Sun et al. [75], Li et al. [76] and Agista et al. [77].

**Review of Thermal Processes:** Cyclic steam injection, steam flooding and most recently Steam-Assisted Gravity Drainage (SAGD) have been the most widely employed recovery methods of heavy and extra-heavy oil production in sandstone reservoirs during last decades. Thermal EOR projects have been concentrated mostly in Canada, former Soviet Union, U.S. and Venezuela, with lesser concentration in Brazil and China. Good examples of steam injection projects of four decades practice are in Yorba Linda and Kern River fields in California [78] and Mene Grande and Tia Juana field in Venezuela [79,80].

SAGD has received consideration in countries with heavy and extra-heavy oil resources, especially Canada and Venezuela due to its applicability in unconsolidated reservoirs with high vertical permeability [81]. Commercial applications of SAGD process have been reported in McMurray Formation in Athabasca, Canada and SAGD pilot tests reported in China [82], United States [83], and Venezuela [84]. Applicability of SAGD in naturally fractured heavy oil reservoirs was studied [85]. Also, numerical simulations of bitumen recovery using solvent and water assisted electrical heating was carried out [86].

*In-situ* combustion (ISC) has been the second most significant thermal EOR technique for heavy crude oils in the past decades. However, an excessive number of inconclusive or failed ISC pilot projects reported can be attributed to insufficient understanding and inappropriate implementation. High Pressure Air Injection (HPAI) in light oil reservoirs has, therefore, gained greater attention despite a few ongoing ISC projects in heavy oil reservoirs such as Bellevue and West Hackberry fields in the U.S. [15,87], Battrum field in Canada [15,], Suplacu de Barcu field in Romania [88,89], and Balol, Bechraji, Lanwa and Santhal fields in India [15,90-93]. Since year 2000, the number of ISC projects has been steady with 10 projects in sandstone formations [15]. Metal nanoparticles had been used as catalyst under electromagnetic heating for in-situ heavy oil recovery [94]. The status of electromagnetic heating for enhanced heavy oil/bitumen recovery was reviewed by Bera and Babadagli [95]. Also, a comparative study of oil sands preheating using electromagnetic waves, electrical heaters and steam circulation [96] was studied, and the use of electromagnetic and electrical heater was found to be more energy efficient than steam circulation.

**Review of Microbial EOR:** In microbial EOR, bio-surfactants generation and $CO_2$ emission are obtained from hydrocarbons by strains of microbes (developed through gene mutation). Microbial injection are achieved through: (i) bacterial cultures mixed with a food source (especially carbohydrate such as molasses); (ii) nutrients to nurture existing microbial bodies and cause bio-surfactants generation to metabolize reservoir oil [97] at the oil-water interface area causing oil droplets formed from the larger oil mass to migrate to the wellhead; (iii) the higher melting point of paraffin, a major component of crude oil, causes it to solidify as it is cooled during the upward flow into the Earth's surface; hence bacteria capable of breaking these paraffin chains into smaller and more mobile chains are injected into the wellhead [98]. The bio-surfactants generation approach has been used in oilfields near the Four Corners and in the Beverly Hills Oil Field in Beverly Hills, California, United States [97].

In China, microbial EOR field tests have been conducted on more than 4600 wells; all the field tests have yielded increase in oil production and reduction in water cut though the screening criteria needs to be improved upon [99-106].

## 3. DISCUSSION

### 3.1 Assessment of Nigeria's Present EOR Status

At present, some companies have already employed water flooding in some deeper reservoirs in Nigeria for pressure maintenance and oil recovery. And preparation is in gear towards implementing tertiary (or enhanced) oil recovery [11] based on findings from various EOR simulations and laboratory works (IFT reduction, wettability alteration and core flooding.

## 3.2 Assessment of EOR Applicability in Nigeria

The efficiency of an EOR method depends on the reservoir characteristics, the nature of the displacing and displaced fluids, and the arrangement of production and injection wells. Reservoir lithology is one of the screening criteria for EOR methods, often limiting the choice of applying precise EOR methods. Most EOR projects are employed in sandstone reservoirs; hence based on lithological considerations, all EOR methods are feasible in Nigeria.

**Immiscible injections of $CO_2$ and nitrogen/flue gas:** In developed nations especially the United States, because of the high value of hydrocarbons and its derivatives, it is generally felt that HC gas injection would be costly under current or future economic conditions. For this reason, attention has turned to the use of $CO_2$ for EOR [107,108]. However, in many countries, the insufficient $CO_2$ availability at the flood front is the major shortcomings of $CO_2$ injection. The major setback of $CO_2$-EOR in Nigeria is that sources of $CO_2$ are few and its transportation is virtually non-existent. Hence, the use of $CO_2$ and nitrogen/flue gas is not a good choice for EOR in Nigeria at present.

**Miscible gas injection:** Miscible gas injection processes are HC gas injection, carbon dioxide ($CO_2$) injection, and nitrogen/flue gas injection carried out at a pressure above the minimum miscible pressure (MMP) to effect multi-contact miscibility (MCM) with zero interfacial tension (IFT) through vaporizing and condensing gas drive mechanisms. Miscibility is a function of pressure, temperature and phase composition.

It is projected that gas injection as an EOR process will continue to grow in future year because it can be applied to a wide range of reservoirs with favorable economic outcomes [109,110]. The depths of Nigeria's reservoirs with their crude oil properties are favorable for miscible gas injection. Also, most light oil carbonate and sandstone reservoirs meet the criteria for any of the miscible gas injection processes [111]. Nigeria had been noted for her light to very light crude oils; hence miscible hydrocarbon gas injection is a good EOR technique to be practiced in Nigeria. However, gas availability or supply and cost are the major determinants in the choice of the type of injection process.

In Nigeria, since the discovery of oil, associated natural gas has been consistently flared and the immediate consequences of flaring include revenue loss, greenhouse gas (GHG) emission, subsequent increase in Nigerian atmospheric temperature and at large global warming which results in climate change. Though large volume of gas requirement makes HC gas injection expensive, yet it is by far more economical to implement HC gas injection than practicing gas flaring; besides, the HC gas injected are not wasted but stored in the depleted reservoir. Also, since the use of $CO_2$ and nitrogen/flue gas is not a good choice for EOR in Nigeria at present, hydrocarbon (HC) gas injection is a very good EOR choice in Nigeria.

**Chemical flooding:** Alkaline or caustic solutions are injected to produce in-situ surfactant that lowers the interfacial tension. Akpoturi and Ofesi [112] carried out laboratory core flooding to investigate the use of locally sourced alkaline in improving light oil recovery from sand samples. The efficiency of the local alkaline (palm bunch ash) was compared with other traditional alkaline (NaOH, KOH and $Na_2CO_3$). Core flooding results showed that oil recovered by KOH, NaOH, $Na_2CO_3$ and palm bunch ash are about 74%, 66%, 59% and 64% respectively. This shows that palm bunch ash is a good candidate for alkaline EOR in Nigeria.

Surfactant flooding alters wettability from oil-wet to water-wet (rock/fluid interaction) and reduces crude oil-formation water interfacial tension (fluid/fluid interaction) [113-116]. A major drawback in surfactant flooding is adsorption of surfactant on rock surfaces especially at low flow rate [114].

In polymer flooding, water-soluble polymers are injected to increase the viscosity of the water. In terms of sweep efficiency, polymer flooding is the most important chemical EOR method in sandstone reservoirs based on the review of full-field case histories. Hence, chemical flooding is a good EOR choice in Nigeria.

**Thermal processes:** Thermal methods lower mobility ratio by decreasing oil viscosity. Since the effect of temperature is especially pronounced for viscous crudes, these processes are normally applied to heavy and extra-heavy oil resources. Sandstone reservoirs are good candidates for thermal EOR projects, hence thermal EOR is a good choice in Nigeria based on lithological consideration. However, the cost implications of the additional heat treatment facilities needed for cyclic steam injection, steam-assisted gravity drainage, and *in-situ* combustion may be major impedance to implementing thermal EOR processes in Nigeria.

**Microbial EOR:** Though microbial EOR is environmental friendly, it is the cheapest; it is not favorable in high temperature (above 85 $^{o}$C), high salinity (above 100,000 ppm) and deeper (beyond 3,500 m) reservoirs. A major drawback of microbial EOR method is bio-corrosion.

### 3.3 Assessment of EOR Prospects in Nigeria

**Technical Benefits:** Some technical benefits of EOR are utilization of existing infrastructure and a few new installations of reduced cost, available reservoir geological and engineering data, improved mobility ratio compared to that obtained in water flooding hence high certainty of recovery.

**Economic Benefits:** Globally, governments' interest in EOR has been attributed to a number of factors. The most obvious is the potential of EOR to propel substantial economic growth through increase in oil production and job creation; also, countries that are able to increase their oil production would of course lower their demand for oil imports. The revenue accrued to the government could be used to drive sustainable developmental projects and meet other socio-economic needs of the people. Another economic benefit of EOR is absence of exploration cost and risk.

**Local Content Development:** In Nigeria, the emergence of offshore oil and gas operations and the granting of deep water acreages to the oil producing companies have led to the neglect of many marginal onshore fields. However, these marginal fields should be leased out to operators of smaller companies especially the indigenous ones for production through EOR. This would, of course, improve local content development and create more jobs for Nigerians.

### 3.4 Assessment of Technical Challenges of EOR Practices in Nigeria

Effective evaluation of reservoir geology and formation characteristics, conducting researches into cost effective EOR methods, and effective training of recruited technical staff for proper operation, surveillance and maintenance of EOR projects are some of the technical challenges.

Gas flaring practices is a major operational challenge facing the current ongoing reforms at making the oil and gas sector in Nigeria more vibrant and attractive for investment; the reforms give strict attention to Nigerian Gas Master Plan.

EOR in offshore fields is not only constrained by reservoir lithology but also by surface facilities and environmental regulations, among other factors [117-119]. Therefore, availability of EOR options in offshore fields is more limited than the onshore counterparts.

### 3.5 Assessment of Economic Challenges of EOR Practices in Nigeria

Some economic challenges in EOR practices in Nigeria include managing and controlling inflation rates, interest rates on loans, general price stability, tax policy, and import duties on machineries and equipment used for EOR.

### 3.6 Assessment of Legal Challenges of EOR Practices in Nigeria

Development of necessary legal and regulatory framework and incentives from the government is a challenge to overcome for successful implementation of EOR in Nigeria.

### 3.7 Assessment of Environmental Challenges of EOR Practices in Nigeria

The Niger Delta crisis is a culmination and expression of built-up anger and frustration by a people from whose lands and rivers the bulk of Nigeria's revenue is exhumed in the form of oil and gas, which translates to billions of dollars yearly, but with the people of the area left in squalor, neglect, abject poverty, and in a general state of underdevelopment. Therefore, there are always the issues of restiveness and unemployment in the host communities where oil and gas exploration and exploitation take place.

More time is spent on enhanced oil recovery projects than those spent on primary recovery and water flooding; the implication is that more injection gases and chemicals would be used and there would be more emissions in the form of dust, exhaust, and off-well gases. Injection and discarded chemicals (containing toxic metals and radioactive substances) could leak into the soil and underlying aquifers if not properly handled, stored and inspected. $CO_2$ capture and sequestration especially from thermal EOR projects is another environmental challenge. Also, there could be epidemics in the oil-producing community due to the pathogenic consequences of microbial EOR practices.

## 4. CONCLUSIONS

At present, EOR is yet to be applied in Nigeria, though it was reported that by December 2008 approximately 52 billion barrels of crude oil were potential targets for EOR in Nigeria. Hence, this paper reviews the global trend of EOR practices and Nigeria's present EOR status, and discusses the prospects, and the technical, financial, legal and environmental challenges of EOR in Nigeria.

Most EOR projects are employed in sandstone reservoirs; hence based on lithological considerations, all EOR methods are feasible in Nigeria. However, miscible hydrocarbon (HC) gas injection is found to be a very good EOR choice in Nigeria because it is by far more economical to implement HC gas injection than practicing gas flaring; besides transportation of carbon dioxide ($CO_2$) and flue gas is virtually non-existent. Another good EOR choice in Nigeria is chemical flooding (in the form of polymer flooding, polymer-surfactant flooding, and alkali-surfactant-polymer flooding) because of its wide application in sandstone reservoirs. However, the cost implications of the additional heat treatment facilities needed for cyclic steam injection, steam-assisted gravity drainage, and *in-situ* combustion may be major impedance to implementing thermal EOR processes in Nigeria at present. Though microbial EOR is the cheapest, it is not favorable in high temperature (above 85 $^oC$), high salinity (above 100,000 ppm) and deeper (beyond 3,500 m) reservoirs. It also causes bio-corrosion..

Some benefits of EOR are absence of exploration cost and risk, utilization of existing infrastructure, available reservoir geological and engineering data, improved mobility ratio, substantial economic growth through increase in oil production and job creation, and improvement in local content development.

## 5. RECOMMENDATIONS

For EOR practices to thrive in Nigeria there should be an extensive economic evaluation and forecasting, effective research and development in the areas of EOR, effective training of recruited technical staff for proper operation, surveillance and maintenance of EOR projects, low inflation rates, low interest rates on loans, general price stability, favourable tax policy, low import duties on machineries and equipment used for EOR, and modified private market decisions. Also, necessary legal and regulatory framework should be developed for successful implementation of EOR in Nigeria.

Gas flaring practices should be curtailed by channeling and utilizing the gas for EOR among other existing and prospective gas utilization projects. This, of course, is in line with the current ongoing reforms at making the oil and gas sector in Nigeria more vibrant and attractive for investment; the reforms give strict attention to Nigerian Gas Master Plan.

To address the issue of restiveness and unemployment in the host communities where oil and gas exploration and exploitation take place, capacity building through provision of education, small and medium scale enterprises should be put in place.

Health, safety and environmental (HSE) considerations relating to injection and discarded chemicals, and emissions should be given priority when operating EOR facilities; also, employees should be trained on their HSE responsibilities.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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