http://dx.doi.org/10.5455/sf.39386

Science Forum (Journal of Pure and Applied Sciences)

journal homepage: www.atbuscienceforum.com

Enhanced oil recovery using CO_2, mitigating climate change and prolonging matured oil wells: A perspective for Nigeria

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ABSTRACT

Are we running out of fossil fuel? If so, how fast is this happening? How are policies and technologies responding to these changes? And what are the alternatives? Today, global policies toward fossil fuel production are rapidly changing toward stringent means (owing to the debate on global climate change) in that "arguably" the change is brought by the release of anthropogenic CO_2 into the atmosphere. A change toward reducing the amount of CO_2 flared during petroleum production into the atmosphere by employing technologies that can capture CO_2 and transport it to matured oil fields has the potential of increasing reserves while achieving a paradigm toward cleaner and environmentally friendly production as well as mitigating climate change. This paper presents a propose perspective for the Nigerian E & P sector in mitigating the scourge of climate change, adaptive for smarter future growth, and prosperity in an cost effective manner through the capture of anthropogenic CO_2 and injecting it back into matured oil wells for enhance oil recovery.

ARTICLE INFO

Article history:
Received 26 March 2019
Received in revised form
15 May 2009
Accepted 16 May 2019
Published 27 June 2019
Available online 27 June 2019

KEYWORDS

Anthropogenic CO_2
Enhanced oil recovery
Climate change
Perspective

1. Introduction

Perhaps one of the greatest, almost unkind and unthinkable to some is the idea that the widely known and almost only cheap source of energy (petroleum) has an inhumane side of its tale. Production of "petroleum," an essential energy source that fuel wars and revolutionized our industries since the last half of the nineteen century, is today facing serious criticism from environmentalists owing to issues related to climate change in responds to anthropogenic activities. The amount of anthropogenic CO_2 flared into the atmosphere has been primarily attributed as the main cause of climate change although it is still being debated among scientist whether CO_2 has anything to do with the changes or the changes we witness are just following the natural climate pattern. However, the global concern has pressured governments round the world to legislate measures to curb this "menace" (e.g., the Kyoto Protocol) (World Coal Institute, 2009). It has now became clear, especially for the Exploration and Production (E &P) industries that to stay in business with this folds of developments, creative and innovative measures has to be put in place to address

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alternative ways of production, one that will reduce the amount of anthropogenic CO_2 footprint while keeping business effectively moving.

One of the sustainable, economical as well as environmentally friendly ways employed to reduce the amount of anthropogenic CO_2 in the atmosphere is through the capture of anthropogenic CO_2 and use for enhanced oil recovery (EOR) in matured oil wells (Wilson and Miller, 2006). This has the tendency of increasing oil reserves while moderating the rate at which global temperature is rising.

This paper stresses some of the positives and alternatives available in the practice of CO_2 EOR in Nigeria with view to particularly stimulate the Nigerian E & P sector into looking at the feasibility of EOR practice as a long term alternative for future growth while curbing climate change.

2. Anthropogenic CO_2 Footprint in Nigeria from Petroleum Production

So far, there are no available statistics onto the actual amount of anthropogenic CO_2 flared from petroleum production in Nigeria; however, many sources utilize indirect empirical quantitative and qualitative means to arrive at an approximate figure. The establishment of the Nigerian gas flare tracker system in collaboration with the US National Oceanographic and Atmospheric Administration to monitor the amount of Green House Gasses as well as CO_2 flared from petroleum production observed on Geographical Information System (GIS) online map generated from signals received from satellite data over time is a welcome development in that realm (Nigerian Gas Flared Tracker Briefing Document, 2014).

However, annual global anthropogenic CO_2 from flaring is estimated to contribute a total of 400 million tons to the total GHG emission, which represent about 1.5% global CO_2 emission (www.newfuelsalliance.org/NFA_PImpacts_v35.pdf). Of this, Nigeria flare about 14% of the total gas flared in 2004 ranking Nigeria second only to Russia which account for 16% globally (www.eia.gov/beta/international/country.cfm?iso=NGA), currently, Nigeria is ranked third behind Venezuela and Russia. Nigeria's annual flaring currently stands at about 36.79 bcm (billion cubic meter) of natural gas (Otene et al., 2016) and about 0.0392 bcm per day (Department of Petroleum Resource, 2013). Most of this is contributed in decreasing order by multinational oil companies such as Shell (SPDC), ExxonMobil, Chevron, Total, ENI (NAOC), Addax-Sinopec, and others (Farina, 2011). It is a common fact that the most part of the production gases in Nigeria are flared by burning into the atmosphere due to issues, such as reservoir pressure stability control, safety, emergency, maintenance, and management of gas during compression and processing; however, because the flared gas is valuable, companies rather capture than flare it. Figures show that about 11 billion USD was lost annually between 1999 and 2009 from gas flaring alone (Anomohanran, 2012). If this much could be saved and utilized for further growth, especially looking at the option of CO_2 EOR, this may turn around profit margin of companies involve.

2.1. What about climate change?

It is no longer a myth that the global ambient temperature is rising and this has been greatly attributed to anthropogenic activities, especially with regards to the amount of CO_2 release into our atmosphere. Whether or not, this is related to humans may not be the relevant issue for the E & P industry today. This is because stringent laws are already in place round the world to deal with issues of unaccepted levels of CO_2 emission. An example of this is the Assigned Amount Units that was binding on the 40 nations that are signatories of the 1997 Kyoto Protocol which led to issues of carbon credits to cancel out your carbon debt (DFID, 2009). Although the amount contributed by CO_2 from flaring represents a minor fraction, this is a part of the bigger picture as far as climate change is concern and something has to be done. In Nigeria and elsewhere, research has shown that the CO_2 flaring is mainly affecting environmental degradation, health risks, and economic loss to the local oil producing communities (Amaechi and Ekene, 2016) but penalty for flaring per cubic meter are rising (about N11,000 per 28.3 m^3) (Opafunso, 2005). This is a prove remainder that something has to be done and be done fast.

2.2. The scary picture

According to the Intergovernmental Panel on Climate Change (IPCC), the global climate is warming and this is happening at an alarming rate. Investigation has shown that the last three decades (between 1983 and 2012) has been successively warmer at the Earth's surface than any proceeding decade since 1850 (IPCC, 2014a). This has been attributed mainly to the levels of GHG emissions generated by anthropogenic activities which have continued to increase over 1970 to 2010 with the largest increase between 2000 and 2010 (IPCC, 2014a). The research has shown that CO_2 (a common GHG) has contributed about 78% of the total GHG emissions increase inherent from fossil

fuel combustion and industrial processes combined between 1970 and 2010 (IPCC, 2014a).

The resulting effect of this warming include but not limited to melting of polar ice sheet, global sea level rise (reclaiming, especially coastal communities), ocean acidification, intense storm events and flooding, and extreme drought. These collectively give a bigger picture of a startle ecosystem that not only affect humans but anything that is within the same system. Studies have shown that communities that will be hard hit by climate change impact are mostly third world nations (IPCC, 2014b; Wellcome Trust, 2009) culminating into health problems (such as El-Nino Southern Oscillation), displacement of communities, and loss of lives and properties (Wellcome Trust, 2009; World Meteorological Organization, 2009).

3. Aspects of CO_2 EOR Feasibility

CO_2 EOR (Fig. 1) order wise technically known as miscible CO_2 Flood EOR is a tertiary recovery technique employed by E & P industry to recover left over oil in their natural reservoirs. It has been employed for more than three decades in the North Americas and the United Kingdom. It involves the capture of anthropogenic CO_2 and injecting it back into matured oil wells where the natural pressure has drop and oil cannot be produced in the conventional sense. CO_2 has the ability to mix with the left over oil to reduce viscosity and cause swelling which in turn improves pressure within the reservoir to enable it ones more recover 30% to 60% of its original oil (Wikipedia, 2018a). This has the potential of preventing the venting of CO_2 into the atmosphere and lowering the rate at which global temperature is rising while achieving a prolonged productive economic growth, as well as permanently sequestering CO_2.

The broader aspects of CO_2 EOR feasibility in a country may be divided into governmental, economical, technical, environmental, and sociological. Generally, the government has to make laws, by-laws, and policies while take a looking at the global conventions and protocols that were signed and agreed upon by the member nations whom are signatories that will serve the best interest of the nation for a prosperous and sustainable future oil production. Economic models should then be a driving force for the effective implementation of the CO_2 EOR operation while looking at both the technical aspects as well as technologies that may be required. The overall benefit should then be the reasonable reduction in the amount of CO_2 flared into the atmosphere which has a huge environmental impact while increasing profit margin and promoting good social harmony, especially to the hosting communities.

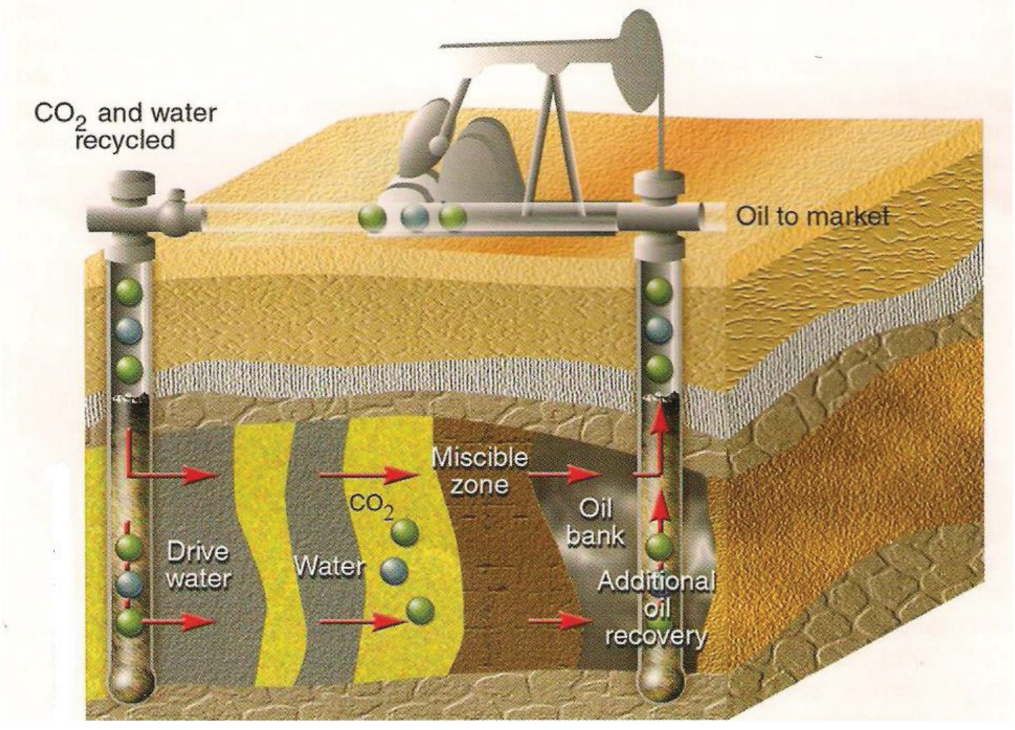

Figure 1. Schematic cartoon depicting CO_2 EOR in practice [modified from Wardle in Riding et al. (2003)].

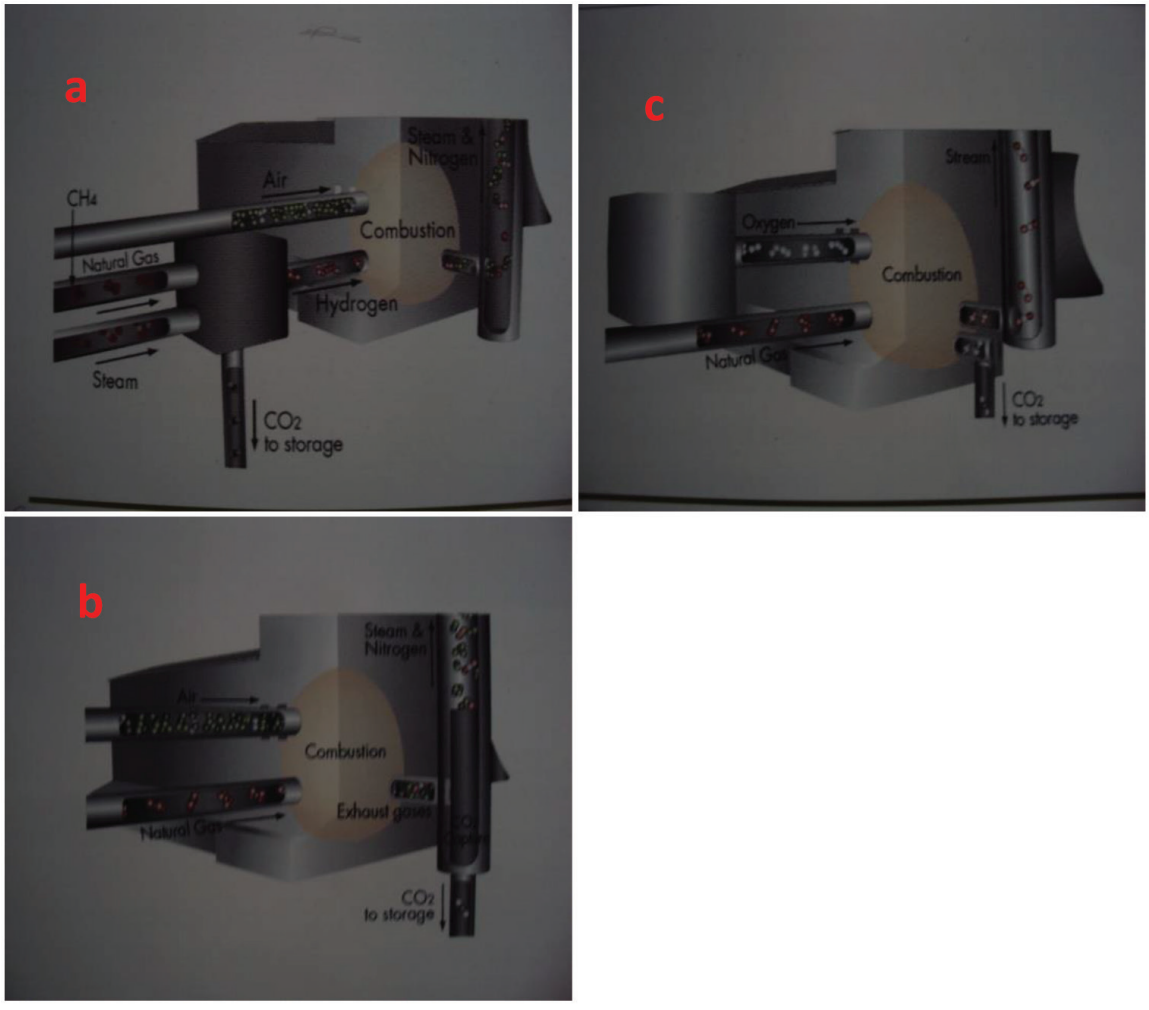

Figure 2. Schematic cartoon showing three ways CO_2 can be captured from fossil fuel. (a) Pre-combustion CO_2 capture; (b) post-combustion CO_2 capture; and (c) Oxyfuel combustion capture [adapted from World Coal Institute (2007)].

At the time of this paper, there is no single oil field known to this research that practices CO_2 EOR in Nigeria. However, this assertion may be due to the paucity of well documented information released to the public domain regarding oil field operation around the 159 oil fields and 1,481 oil wells (Wikipedia, 2018b) in the country. Although Nigeria is one of the few major oil producing nations capable of increasing its production capacity (currently, standing at 2.53 million barrel per day) from its ever increasing 37.2 billion barrels of proven oil reserves (NNPCGROUP, 2018), it is essential for government and companies, especially the E & P to look for practical alternatives, such as CO_2 EOR, that will increase their output for a sustainable future growth.

Looking at the factors, such as population, increasing consumption, availability, and affordability of alternative energy sources (such as green technologies), economic growth and marketing possibilities, there is no doubt that fossil fuel is still going to be a major energy source for more years to come.

3.1. CO_2 capture, transportation, and storage options

Currently, there are three main ways that we can capture CO_2 in the oil and gas industries. These have been employed for more than 60 years (World Coal Institute, 2007), they include: (1) Pre-combustion CO_2 capture (Fig. 2a) which involves the capture of syngas produced from fossil fuel before combustion and convert it via a steam based chemical reaction into separate streams of CO_2 and hydrogen (H) which is collected in supercritical form suitable for transportation, (2) Post-combustion CO_2 capture (Fig. 2b); this is a chemical absorption process which separates CO_2 from fossil fuel produced through combustion, and (3) Oxyfuel combustion (Fig. 2c); this involve restricted

combustion of fossil fuel in pure oxygen rather than air to enhance the concentration of CO_2 while avoiding the introduction of nitrogen into the combustion cycle which in turn makes it easier to capture and compress CO_2.

The safest and cheapest way of transporting the CO_2 capture from where it was captured to where it is needed is done through network of pipelines which are readily available throughout Nigeria. Because CO_2 is largely inert, it is easily handled and transported in high pressure pipelines. Places that could not be reached via pipelines can be supplied by road transport using special trucks or via ships.

For a sustainable growth, a constant supply of CO_2 to potential fields has to be secured; in this respect provision for storage has to be in place. In Nigeria, varieties of storage options and domain do exit. One of these is the abundance of inland-basins that can serve the purpose of CO_2 storage within deeply buried horizons of sandstones of high reservoir integrity. Currently, there are ongoing exploration activities within these inland-basins; whether or not, commercial discoveries of oil and gas are made the basins can fit into the economic options in the case of large scale future CO_2 EOR project for the E & P industries.

4. Conclusion

Given that Nigeria is a major player in the global fossil fuel business owing to its huge petroleum reserve, it is often becoming continuously apparent that future production has to tackle issues of excessive GHG flaring looking at emerging global regulations that are trying to deal with excess flaring of GHG, especially CO_2 during production due to its impact on climate change. CO_2 EOR offers an option for just that; it has the ability to cut down the amount of CO_2 being flared while improving oil recovery in matured oil wells. However, because this technique is relatively new, policies and regulations have to be made that will facilitate and encourage the implementation of CO_2 EOR. Parts of the feasibility aspects needed for effective regional CO_2 EOR implementation, such as storage and transportation, are already viable in the country. The E & P industries in Nigeria has to look into the option of practicing CO_2 EOR for the numerous values it offer both in long term and near future growth through the development of a technically and commercially viable frameworks. This will go a long way in contributing to the global effort in lowering the rate at which global temperatures are rising while creating mutual benefits to the hosting communities.

Acknowledgments

The authors wish to express their profound appreciation to the following organizations for their resource support over the years of this research: (1) The British Geologic Survey (BGS) Keyworth, Nottingham Office; (2) The Henry Wellcome Trust UK; (3) The Intergovernmental Panel on Climate Change (IPCC) Geneva, Switzerland; (4) The World Coal Institute (WCI) at Putney, London and; and (5) British Petroleum (BP) in Hampshire, UK.

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