Analysing the Concept of Environmental Sustainability in Oil and Gas Operations in the Global South: A Case Study of Nigeria – Niger Delta

Rasaki T. James, Titus K. Olaniyi, Posi Olatubosun
Sustainable Energy and Allied Disciplines
Glasgow Caledonian University, London

Abstract

This paper analyses the concept of sustainability in oil and gas operations in the Global South (GS) using the Nigeria Niger Delta as a case study. Over the years, countries around the world have relied on oil and gas for energy security, economic growth, self-sufficiency and to gain geopolitical advantages. The exploration and production of oil and gas continue to be a priority in producer countries of the GS with regulations and policies being implemented to enhance the sustainability of the industry. In 2018, before the pandemic, global energy production was 14 421 Mtoe, an increase of 3.2% compared to 2017; mainly driven by coal, oil and gas. Thus, despite the global sensitisation towards renewable energy, oil and gas continue to play a key role in shaping world economies. Globally, producing countries and oil and gas companies face the increasing demand to explain how they can contribute to the reduction of greenhouse gas emissions and the achievement of Paris Agreement goals. This has necessitated energy companies to carefully consider adapting their operations, policies and business models to reduce the impacts of oil and gas operations on the environment. Therefore, sustainability has been an overarching theme over the past decades and industries including oil and gas have the responsibility to incorporate sustainable practices in their operations and policies. research investigates the environmental sustainability issues of oil and gas operations in the Niger Delta region in Nigeria.

Keywords*: Global South, Oil and Gas Operations, Niger Delta, Sustainability and Nigeria*

1. Introduction

Over the years, countries around the world have relied on oil and gas for energy security, economic growth, self-sufficiency and to gain geopolitical advantages [1]. The exploration and production of oil and gas continues to be a priority in producer countries of the Global South with regulations being implemented to enhance the sustainability of the industry [1,2]. In 2018, before the pandemic, global energy production was 14 421 Mtoe, an increase of 3.2% compared to 2017; mainly driven by coal, oil and gas. In total, fossil fuels accounted for up to 85% of global energy production the same year [3]. Thus, despite the global sensitisation towards renewable energy, oil and gas continue to play a key role in shaping world economies.

Globally, producing countries and oil and gas companies face increasing demands to explain how they can contribute to the reduction of greenhouse gas emissions and the achievement of Paris Agreement goals [3]. This has necessitated energy companies to carefully consider adapting their operations, policies and business models to reduce the impacts on the environment. On the one hand, the global society is faced with combating climate change, global warming and other negative impacts of oil and gas production on human lives. On the other hand, accessing affordable energy is key to human survival, especially as renewable energy prices are still beyond the reach of the ordinary. In the 21st century, striking a balance between these two extreme situations is the quest of energy companies, producing countries, policymakers and researchers.

Most oil and gas producing countries of the Global North such as the United Kingdom are implementing sustainable measures in energy production [4]. However, on a large scale, Global South is yet to effectively tackle the attendant environmental and health impacts resulting from oil and gas operations. In the Niger Delta region in Nigeria which is the case study of this paper, environmental degradation resulting from oil and gas operations continues at an unprecedented rate [5]. Nigeria belongs to the Organization of the Petroleum Countries (OPEC), it is the sixth-largest exporter of oil. The country which derives more than 90% foreign exchange from petroleum products also undergoes (host communities) more than 90% socio-economic and environmental degradation [5,6].

The Niger Delta communities continue to suffer from high incidences of oil spills which have grave negative impacts on the environment. The indigenes have taken to protests, agitations, demonstrations and violence to express their dissatisfaction with the deplorable environmental degradation [7]. Despite this, the International Oil Companies (IOCs) continue to operate with greater impunity. Oil spillages regularly occur in the Niger Delta region of Nigeria. As of 2018, there had been up to 9500 incidences of oil spill in a decade. Annually, on

 | DOI: 10.20533/ijsed.2046.3707.2023.0063

average about 115, 000 barrels (equivalent to about $5 million worth) are spilt into the environment [8]. Continuous high incidences of oil spills have destroyed the ecosystem, with adverse effects on marine life and the mangrove. Oil spills pollute farmlands and rivers, thereby destroying the means of livelihood of the indigenes as well as harming human health [9].

2. Problem Statement

Oil and gas operations in the Nigeria Niger Delta region have resulted in environmental degradation through high levels of oil spillages and gas flaring [10]. Oil and gas exploration and exploitation damage vegetation cover; causing a high risk of erosion, due to the lack of a robust environmental management plan [11]. The non-standard practices of local refiners result in oil spillages, wiping off more than 50,000 acres of mangrove forest [12, 13, 14]. In the same vein, the unwholesome disposal of wastes like Produced Water (PW), drilling muds and cuttings pose serious environmental health risks. This practice also destroys the mangroves and aquatic organisms [11]. Gas flaring is another major cause of environmental degradation in the Niger Delta region. Due to the lack of technology to harness flared gas, the practice contributes to climate change, and soil acidity, causing depletion of soil nutrients and loss of crop yields [15, 16].

The unabated environmental degradation in the NDR has negatively affected the means of livelihood (fishing and farming) of the people [17] due to the disturbance of the marine and depletion of soil nutrients. Furthermore, environmental laws have been ineffective in tackling environmental hazards caused by the production of oil and gas in the NDR [5, 15], caused majorly by administrative bottlenecks and corruption [18]. The deplorable environmental condition caused by oil and gas operations in the NDR often lead to widespread protests and conflicts; resulting in brutal and indiscriminate reprisal of the protestants by the government. An example is the execution of Ken Sarowiwa and eight other Ogoni leaders on November 10 1995 [19].

Over the years, the energy playing field has been dominated by hard modelling techniques and approaches put forward by researchers in the economics and engineering disciplines [20]. However, in certain scenarios, some of these approaches have not effectively solved the complexities presented. The optimization modelling approach is designed to find the best way (optimum) of solving a problem. The efficacy of this modelling is in its application to a small sample of data set [21]. The Econometric modelling approach specifies what statistical relationship exists between the model variables (quantities and prices) and model parameters [22]. For the econometric model to be effective in energy planning, large quantities of data from the past and aggregate data are essential to reduce the fluctuations over time [23]. The model also relies on statistical methods to achieve better results, which may not be suitable to the Niger Delta scenario.

Given the complexity of the Niger Delta situation, traditional modelling approaches have not been effective in solving the environmental issues caused by energy development. In sustainable energy development and operations in the Niger Delta region, this paper adopts the use of the Systems Thinking/System dynamics (ST/SD) [24]. This is because it is a holistic tool that is capable of capturing the non-linearity, feedback, and delays embedded in the oil and gas operations process and activities in the Nigeria NDR. Figure 1 captures vividly the myriad environmental sustainability issues in the NDR.

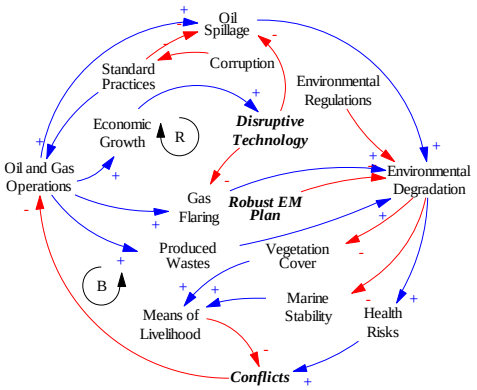

Figure 1. NDR Environmental Causation Sustainability Drawn using Vensim PLE

The Figure 1 demonstrates that oil and gas operations in the NDR result in oil spillage, gas flaring, produced wastes, conflicts, health risks etc. However, the issues can be addressed by disruptive deregulations, standard practices, robust environmental regulations, and policies.

3. Literature Review

Sustainable Issues in the NDR - Sustainability as described by the Brundtland Commission (1987) is meeting the needs of the present generation without compromising the ability to meet the needs of the future generation [25]. Albert, Amaratunga and Haigh [5] state that despite Nigeria realizing more than 90% foreign exchange from petroleum products, the NDR has been subjected to more than 90% socio-economic and environmental degradation. Through a qualitative research methodology (interviews and group discussions), the authors highlight succinctly how oil spill incidences have left the region to be one

 | DOI: 10.20533/ijsed.2046.3707.2023.0063

of the worse impacted globally. In a comparative analogy, they conclude that in 40 years, the Eurozone experienced just 10 incidences of oil spills, whilst Nigeria experienced over 9,000 cases in ten years. Furthermore, the authors argue that in 50 years, up to 13 million oil barrels spilt in the Nigerian environment is equivalent to about 50 Exxon Valdez oil spills of 1989.

In consonance, Oka [13] analyzing data collected from secondary sources, notes that the rich mangroves, tropical rainforest and the aquatic environment of the Niger Delta region, have been devasted by oil spillages. The author highlights that between 1986 and 2003, more than 50,000 acres of mangrove forest were wiped off. He states further that between 1976 and 2000, oil spill incidences affected 6% of the landmass, 25% swampy area and 69% of the offshore environment. Also, the water resources, arable lands and plant species that support a population of more than 20 million communities such as Ogoni, Ughelli and Oyakama have been battered. The author concludes that despite the scale of environmental degradation, it is business as usual for oil companies operating in the region, with no implementation of effective sustainable measures.

Giwa et al. [26] state that gas flaring occurs when natural gas is oxidized rapidly which results in the release of gases, heat and particulates into the atmosphere. Through forensic analysis of data from secondary sources, they conclude that over a period of 50 years, 917.7 x 10 9 m3 of 1.78 x 1012 m3 of gas produced in the NDR was flared. This has constituted immensely to the environmental health risk of the people. In the study, they highlight that flared gas (FG) does not only contribute to global warming and climate change but is also a source of volatile organic chemicals, greenhouse gases, particulate matter and black carbon. The authors further note that toxins such as Sulphur dioxide, toluene, benzopyrene, xylene and hydrogen sulfide are associated with FG which cause air, water and soil pollution. This has an irreversible negative impact on vegetation, ecosystem, public health and environment.

Edwin and Ugbomeh [27] analyzing data collected from secondary sources state that annually Nigeria flares over 17 billion m3 of natural gas with negative effects on biodiversity and wildlife, human health and climate change. The authors note that the benefits of biodiversity include cultural conservation, air and water purification. They argue that gas flares which contain more than 250 toxins contributed to about 100% loss of crops yields cultivated within the vicinity of the Izombe station in the NDR. Furthermore, they state that gas flaring contains contaminants like hydrogen sulfide, hydrocarbons and ash which acidify the soil, resulting in the depletion of soil nutrients. Other effects of gas flaring on crops noted by them include stunted growth, withering and scorched plants.

Yakubu [11] states that oil and gas exploration and exploitation involve amongst others tree-felling, seismic activities, drilling, equipment installation and the application of explosives to produce sub-surface maps. This results in the damaging and critical alterations of vegetative cover, soil structure, flora population and areal fauna which lead to high risks of erosion. The author affirms that some of the waste products generated from petroleum activities include, Produced Water (PW), drilling muds and cuttings. According to the author PW composes of hazardous chemicals and radioactive materials which are environmentally unfriendly. The unwholesome disposal of these wastes has further aggravated the already deplorable environmental condition of the NDR. The author further states that in 2011, the UNEP assessment of the Ogoni land reported that industrial wastes of about 1000-1500m3 were indiscriminately and unhygienically disposed of; causing severe environmental health risks. This situation continues unremedied with serious negative consequences on the health of the people. The author proposes a robust environmental management plan/system and compliance with environmental laws to remedy the situation.

Trend of Oil and Gas in the Global North - OGUK [28] reinforcing the role of the UK's oil and gas industry in helping to meet global energy needs, notes the trend of change in the energy landscape of the country towards achieving net-zero greenhouse gas emissions by 2050 to combat climate change. The publication notes that the oil and gas industry can contribute immensely in delivering the UK's climate goals through the provision of secure and affordable low-carbon solutions; thus, enhancing a sustainable UK oil and gas industry. The publication further states that the offshore oil and gas industry caters for 45% of the total energy needs of the country and for decades to come. It would continue to provide energy security and huge benefits such as easy access, regulation, control and economic upliftment; emphasising that oil and gas production accounts for 1.2% of the UK's GDP as well as providing revenues through taxes and creating employment. Despite the trend towards a net-zero emission, the performance of the UK's oil and gas industry continues to improve and is more competitive than ever before; attracting new investors to the basins, unlocking fresh opportunities with drilling activities increasing. 3% of the combination of the UK's greenhouse gas emissions stem from oil and gas operations, however, the country puts into practice large-scale mitigation programmes such as Carbon Capture, Usage and Storage.

Simola and Solanko [29] state that oil and gas

 | DOI: 10.20533/ijsed.2046.3707.2023.0063

have played a major role in Russia's economy over the decades and continue to contribute immensely to the country's GDP, in the 200's oil and natural gas accounted for about a fifth of Russia's GDP and 30% of consolidated budget revenue. The authors state further that oil and gas companies are the largest in the country and their weighting in the Russian stock market index amounts to more than half. They affirm that Russia's oil and gas production has been growing steadily annually at the rate of 1%, with the introduction of new fields in Eastern Siberia and Arctic region. They further state that Russia is a major player on the global stage with regards to gas production and this has been growing steadily over the years. In 2016, the country's gas production was 640 billion m3 in comparison to 2015 which was 630 billion m3, new production fields such as the Bovanenkovo field have been introduced on stream. In 2015, Russia exported about 195 billion m3 of pipeline gas of which 163 billion m3 went to Europe, Russia continues to play a leading role in global gas exports.

Karimi [30] drawing from the Norwegian experience, affirms that the oil and gas industry is one of the major sources of CO2 emissions, however recent technological break-throughs in CO2 capture has proven that Carbon capture and storage (CCS) is game-changer in addressing environmental problems caused by gas flaring and its application in a small-scale plant proves that its efficiency is around 80-90%. The author further notes that Sleipner in Norway, is the first CCS project to be fully implemented in Europe and has been capturing 1 million metric tons of CO2 annually and on a large scale, the technology could play a major role in mitigating climate change. The CCS technology in Norway came into existence to reduce GHG emissions due to the growth of gas-fired power plants.

Froggatt et.al. [31] states that climate change (with environmental and public health impacts) has been an overarching factor in global energy transition; making it expedient for industry players to review energy production and consumption. According to the authors, this has greatly influenced Norway's implementation of the CCS technology and other initiatives to reduce its carbon emissions. However, the authors note that despite global concerns about climate change, global fossil fuel consumption is on the increase, as there was a 25% and 37% increase in global oil and gas consumption respectively in 2019. The study emphasises that despite the benefits of the CCS and Carbon Capture and Use (CCU) technologies, global deployment in the oil gas industry has been very slow and global emissions continue to rise, reaching a whopping 51.8 gigatons of carbon dioxide equivalent in 2018.

Perspectives of Sustainability Framework - Clune and Zehnder [32] consider sustainability framework from a multidisciplinary and solutions-oriented approach driven by three pillars of technology and innovation; laws and governance; and economics and financial incentives. According to the authors, this three-pillar framework is strategic because it describes particular and realistic changes that need to take place to enhance sustainability solutions. They argue that technology enhances fewer resources and energy inputs whilst creating new ways of doing things. The economics section considers problems hindering wealth and growth while laws and governance address issues of regulatory baselines and public policy formulation in supporting sustainability solutions enshrined in technology and economics. The study concludes that the three-pillar framework is needed for changes and sustainability objectives to be accomplished.

Adewuyi et al. [33] state that energy plays an important role for Nigeria to realize the Sustainable Development Goals (SDGs) by 2030 as projected by the United Nations. The authors identify gas flaring as one of the major causes of environmental degradation in the Niger Delta area. To manage this situation and harness the gas flared, they propose investments in modern technologies that would generate electricity from natural gas and a radical regulation of the gas industry. They further state that an efficient natural gas reclamation would lead to a reduction in the GHG emissions footprints if deployed to power vehicles.

The Intergovernmental Panel on Climate Change report [34] states that Carbon dioxide (CO2) Capture and Storage (CCS) involves a process whereby carbon dioxide is separated from sources related to energy, compressed, transported and stored for future use. They further state that the technology can capture up to 85%-95% of CO2 released into the atmosphere. Kapetaki, Simjanovic and Hetland (2016) state that CCS is a game-changing technology in combating climate change which enhances sustainable industrial activities. To demonstrate the effectiveness of the CCS, the research compares its deployment on projects in some European Union countries (Norway, Netherlands, the UK and Spain). They affirm that globally CCS would play a major role in limiting the rise in global temperature to below 2 degrees Centigrade.

Cheropovitsyn, Chvileva and Fedoseev [35] in consonance, state that to combat climate change, the deployment of CCS would reduce CO2 concentration in the atmosphere. The authors acknowledge that the technology is not being widely used due to its relative novelty and low-level experience in implementation. They further state that anthropogenic greenhouse gas emissions consist largely of fossil fuels. They stress that as of 2019, combustion-related activities from fossil fuel accounted for 34,169 billion tons of global carbon

 | DOI: 10.20533/ijsed.2046.3707.2023.0063

dioxide emissions which is about 60% and 44% higher than in 1990 and 2000 respectively. To strengthen their argument, they affirm that CCS and Carbon Capture and Utilization (CCU) are effective technological options to reduce anthropogenic carbon dioxide emissions. According to them, CCS involves the process of capturing CO2 from emissions sources, transporting it to a storage site and burying it in a suitable underground geological formation. CCU on the other hand involves the capture of CO2 from sources of emissions which is later used in creating services or products of value which include injecting into reservoirs to enhance oil recovery.

World Economic Forum [36] argues that the deployment of disruptive technology to carry out oil and gas activities is the game-changer that the industry needs. Such disruptive and digital technologies include robotics, drones, global positioning system, horizontal drilling technology, cloud computing, Internet of Things (IoT) storage technologies and digital platform. They stress that these would improve operational efficiencies as well as reduce environmental impacts.

Deloitte [37] embraces digitalizing the oil and gas industry to improve operational performance, safety and reduce environmental impacts. They support the use of seismic imaging to evaluate subsurface formations and geoscience data of thousands of wells in seconds. To strengthen their argument, they state that ExxonMobil uses seismic imaging to determine the distribution of fractures for good optimization. This enhances precision in identifying and drilling commercially viable wells, thereby reducing environmental impacts. They further state that the deployment of 4D seismic models is effective in analyzing and tracking changes in reservoirs. To strengthen their argument, they state that in Canada, advanced vitalization, virtual and augmented reality combined with steam-assisted gravity drainage (SAGD) are deployed in managing their complex reservoirs. Thus, enhancing performance and reducing environmental impacts.

4. Methodological Approach

We use the Systems Thinking / System Dynamics (ST/SD) methodological approach [38] to investigate the environmental sustainability issues arising from oil and gas operations in the NDR in Nigeria. This informs the environmental sustainability framework that could be developed to manage the operations. Qualitative data collected from journal articles, online archives, textbooks and oil and gas journals are analysed to understand the prevailing pertinent issues. Also, semi-structured interviews with key industry players will be carried out. The Systems Thinking / System dynamics (ST/SD) tool is suitable for the Niger Delta situation because traditional econometric and linear programme techniques cannot analyse the non-linear relationships that exist between the system variables in energy systems. Delays which are inherently present in energy systems need to be captured and the interaction of the feedback loops that interact amongst each other must also be captured for modelling to be effective.

The philosophy that underpins this research is interpretivism as it aligns with the qualitative (subjective) approach of the research; allowing for possible interpretations and analysis of the data gathered. Adopting the interpretivism philosophy enhances the creation of a new and better understanding of the issues surrounding oil and gas operations in the region. This allows the divergent views of the stakeholders including the oil producers, Nigerian government, Niger Delta citizens and environmentalists to be considered.

5. Discussion and Findings

Oil and Gas Exploration and Exploitation - Hydrocarbon exploration is the process of searching for deposits of oil and natural gas underground and International oil companies need exploration licenses to be able to extract oil and gas in commercial quantities from a geographical location [39]. Oil and gas exploitation processes include drilling, completing and equipping wells to produce commercially recoverable hydrocarbons in a field [40]. Globally there are 1.45 trillion barrels of proven oil reserves [41]. In the Niger Delta region, oil exploration and exploitation have destroyed large areas of the mangrove ecosystem due to oil spills which have made the habitat toxic [42]. Marine life, ground and drinkable water have been adversely affected by oil exploitation in the host communities as shown in Figure 2 below:

Figure 2. Hydrocarbon Pollution of Surface Water – Ogoni land (Oladipupo et.al.,2016)

As shown in Figure 2 above, most surface water in Ogoni land has been contaminated by oil

 | DOI: 10.20533/ijsed.2046.3707.2023.0063

pollution, thereby destroying the habitats and endangering the health and safety of the people.

Mangroves are important and invaluable to humanity, providing habitat to fishes, improving water quality, enhancing coastal stabilization, serving as a source of fuel and medicinal ornaments, and enhancing carbon sequestration. Overexploita -tion of oil in the Niger Delta region has resulted in the continuous depletion of the mangroves despite its economic and environmental benefits [43]. Mangroves cover most tropical and subtropical coasts; occupying approximately 137,760 km2 – 152,360 km2 of the surface of the globe and in total, about 73 mangrove species across 123 countries are dispersed [44].

Oil Spillages - Nigeria derives about 90% foreign exchange from petroleum products, however, the environment of the host communities suffers more than 90% degradation. Oil spill incidences in the Niger Delta region is one of the highest globally; with the region experiencing about 10,000 incidences in ten years in comparison to 10 experienced in the Eurozone in the same period [5]. The oil companies that operate in the region, continuously denigrate the environment with impunity through incessant high levels of oil spills, with no effective sustainable practice. In 2012, Chevron's gas rig in Southern Ijaw caused accidental oil spillage and severe gas fire which lasted 46 days (Elekwachi et al, 2019). In 2013, between January 2013 and September 2014, NOSDRA reported that about 2,000 oil spill incidences occurred in the core of the Niger Delta with negative impacts on the ecosystem [45]. Mobil Producing Nigeria Limited was penalised 10m naira for not cleaning up the Qua Iboe terminal oil spill in 2015. In the same year, Shell spilt about 40,000 barrels of oil through leakages along the Niger Delta coast which had negative impacts on the offshore eco-system [45].

Effects of Oil Spillages and Gas Flaring - In the Niger Delta, high levels of oil spillage have resulted in the degradation of agricultural lands, consequently increasing poverty levels and turning otherwise fertile lands to waste lands [46]. High retention time of oil in the soil causes poor aeration, affects soil structure, nutrients, temperature, pH and crop yields. Cassava, one of the crops widely planted in the region has been negatively affected by oil spillage. Secondary data analysed shows that causes of loss of cassava production include pest incidence, flooding insufficient processing facilities, poor transportation and oil spillage which is a major factor. Table 1 shows that oil spillage is a major factor in the losses of cassava production in the host communities.

As could be seen in the data presented in Table 1, the frequency of occurrence for each factor that causes loss of cassava production is 51. It is interesting to note that in the host communities, on every occasion of oil spillage, farmers record total loss.

Table 1. Major Causes of Loss of Cassava Production

Causes	Host Communities-Frequency (51)	Non-host Communities – Frequency (51)
Pest/Disease	20	20
Flooding	22	21
Oil Spillage	51	0
Transportation Issues	20	18
Poor Facilities	15	17
Poor Market	5	2

Adapted from Ahmadu and Egbodion (2013)

Gas flaring in the Niger Delta region has; negatively impacted bio-diversity, contributed to global climate change and led to serious health challenges [16]. During the production of oil, associated gas is flared. Globally, the Niger Delta ranks 4th in bio-diversity hot spot and in Africa, it is the largest wetland, richly endowed with biological diversity. World bank data [47] on gas flaring by top 20 countries analysed in Figure 4.2 below shows that as of 2019, Nigeria ranks 7th.

Table 2. 20 Top Gas Flaring Countries – 2019

Countries	**Gas Flared (bcm)**
Russia	23.21
Iraq	17.91
United States	17.29
Iran	13.78
Venezuela	9.54
Algeria	9.34
Nigeria	7.83
Libya	5.12
Mexico	4.48
Oman	2.63
Malaysia	4.48
Egypt	2.34
Angola	2.33
Saudi Arabia	2.10
China	2.02
Indonesia	2.0
Republic of Congo	1.67
Kazakhstan	1.57
Gabon	1.46
Australia	1.39

The Table 2 above shows that, in 2019, Nigeria flared 7.83 (bcm) of gas; majority of which occurred in the Niger Delta region, making the country to rank 7th globally.

In the Niger Delta, gas flaring causes severe harm to the health of the people living close to gas flaring stations. Associated gas flared into the atmosphere contained harmful substances such as toluene, benzene, dioxin, Sulphur dioxide as well as

 | DOI: 10.20533/ijsed.2046.3707.2023.0063

Greenhouse gases. Secondary data analysis reveals that residents living close to gas flaring stations are at a higher risk of diseases relating with air pollution such as asthma, cough, chest pain, breathing difficulty, dizziness and eye irritation [48]. Gas flaring causes the release of greenhouse gases such as carbon dioxide and methane into the atmosphere which impact on the ozone layer and causes climate change, which affects mostly low-lying coastal areas such as the Niger Delta region [49]. This results in flooding, coastal erosion, raised temperatures, and rise in sea level; favouring proliferation of pests, spread of diseases and low agriculture productivity.

The greenhouse gases released into the atmosphere as a result of flared gas also contributes greatly to global warming by the trapping of long-wave infra-red radiation in the atmosphere, which warms the earth and thus making the average temperature of the earth to rise [49]. Methane is the major component of natural gas; in Nigeria, natural gas composes of about 90% methane, 2% carbon dioxide, 3.4% propane, 5.3% ethane and 2.4% heavier hydrocarbons [49]. About 52% of the Nigerian total proven gas reserve is associated natural gas which is trapped alongside with crude oil in the reservoir. Due to lack technology to harness associated natural gas which comes as a by-product in the course of producing crude oil, majority of this is flared. Between 2009 and 2015 as outlined in Table 3 (though the trend is on the decrease), a substantial volume is still being flared and this can be further reduced if appropriate technology is deployed.

Table 3. Gas Production and Flaring - Niger Delta (2009-2015)

Year	Gas Produced (Cubic meters)	Gas Flared (cubic meters)	% of Gas Flared
2009	1,837,278,307	509,351,905	27.72
2010	2,392,838,898	581,568,354	24.3
2011	2,400,402,880	619,032,858	25.79
2012	2,580,165,626	588,66,724	22.82
2013	2,325,137,449	409,311430	17.6
2014	2,524,268,444	289,600,014	11.47
2015	2,929,852,323	341,372,264	11.65

Source: Adapted from Rufai et al. (2019)

The Table 3 demonstrates that 27.72% of the total gas produced in 2009 was flared, however, this has been steadily decreasing and in 2015, 11.65% of gas produced was flared. Despite a decrease, the amount of gas still being flared in the NDR is alarming and can further be reduced to the barest minimum with the implementation of sustainable measures. To get a better understanding of the scale of the problem, it has been vividly demonstrated in Figure 3.

The highest volume of gas (619,032,858 cubic meters) was flared and this has been decreasing,

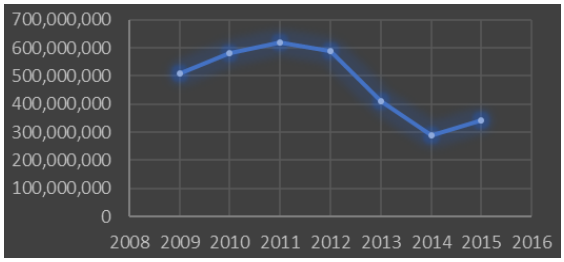

Figure 3. Gas Flared NDR – Cubic Meters (2009-2015)

but in 2015, the trend started to increase, thus the need to arrest the situation by implementing environmental sustainability measures to manage the oil and gas operations in the NDR.

Environmental Degradation and Conflict - Nigeria is a major player in the global energy market, the Niger Delta region is where the country's hydrocarbon reserves are located. Oil and gas operations in this region have resulted in unabated environmental degradation, causing colossal destruction of the means of livelihood (farming and fishing) of the people [50]. Aside from the large-scale environmental degradation in the area, the oil resource has been a curse rather than of any economic benefit to the people. The host communities live in squalor, abject poverty and deplorable condition, despite the huge revenues Nigeria derive from the exploration and exploitation of oil and gas in the region.

This situation has led to the region being embroiled in resistance, insurrection, conflicts and armed rebellion against the Nigerian government and the multinational oil companies. Consequently, the NDR is characterised by intense hostilities, conflicts, and violent confrontations [51]. Youth groups and other interest groups often make demands from the multinational oil companies and when such demands are not honoured, they protest to stop production, vandalise oil facilities, take hostages and seize properties. Sometimes, these conflicts are violent and could result in fatalities. The major concern of the people of the NDR has been high scale environmental degradation which has led to the destruction of their means of livelihood. Other concerns include unemployment, poverty, health problems and the overall underdevelopment of the region. This has often led to conflict and brutal repressions by the Nigerian government.

This unabated environmental degradation often results in protests and conflicts to gain the attention of the government and the International oil companies (IOCs). The NDR situation is such that there is high scale unemployment, poverty and underdevelopment, despite the huge revenues realised from oil and gas operations. Again, as this

 | DOI: 10.20533/ijsed.2046.3707.2023.0063

situation continues without any solution, the citizens resort to vandalism, disruption of operations and taking people hostages. The government would sometimes intervene with repression, brutality, arrests which could lead to the execution of some militant members.

6. Conclusion and Recommendations

Given the foregoing discussions, it is evident that environmental sustainability issues in the Nigeria NDR have continually caused environmental degradation through incessant oil spillages and gas flaring. This has affected the farming and fishing businesses (major sources of income) of the people. It has also impacted negatively on their health and quality of life in general. Despite the huge revenues the Nigerian government derives from oil and gas operations in the NDR, poverty, squalor, conflicts and underdevelopment have been the order of the day. Whilst this paper acknowledges the attendant negative environmental impacts of oil and gas operations, in the NDR, it however takes a standpoint that oil and gas exploitation and exploration continue given its economic benefits to Nigeria as a nation. Notwithstanding, to enhance the environmental sustainability of oil and gas operations in the NDR it makes the following recommendations:

- A complete overhaul of the Nigerian environmental laws and regulations should be carried out; such that violators are held accountable for their actions.
- The Nigerian government energy policy makers need to incorporate robust sustainable measures in energy planning and development for oil and gas companies and other industry stakeholders to adhere to.
- The Nigerian government should take pragmatic steps to encourage investment in technologies such as Carbon Capture and Storage (CCS), Carbon Capture and Utilization. The application of the CCS technology in a small plant in Norway proves to be 80-90% efficient, capturing about 1 million metric tons of CO2 annually and could be deployed on a large-scale to mitigate the environmental impacts of oil and gas operations in the Niger Delta region.
- Lastly, digitalizing the Nigerian oil and gas industry to include the deployment of disruptive technologies such as robotics, drones, global positioning system, horizontal drilling technology, cloud computing, Internet of Things (IoT) storage technologies and digital platform would improve operational efficiencies as well as reduce environmental impacts. For example, Canada uses advanced vitalization, virtual and augmented reality combined with steam-assisted gravity drainage (SAGD) to manage complex reservoirs. This enhances performance and reduces environmental impacts.

7. References

[1] Doric, A., and Dimovski, V. (2018). Managing Petroleum Sector Performance – A Sustainable Administrative Design. Economic Research. 31 (1), 119-138.

[2] Obeng-Odoom, F., (2018). Petroleum Accidents in The Global South. Environmental Impacts of Transitional Corporations in The Global South. Research in Political Economy. 33 (1), 111-142.

[3] IEA. (2020). The Oil and Gas Industry in Energy Transitions. Available: https://www.iea.org/reports/the-oil-and-gas-industry-in-energy-transitions. (Access Date: 6 December 2022).

[4] Yusuf, Y. Y., Gunasekaran, A., Musa., El-Berishy, N. M., Abubakar, T., and Ambursa, H. M. (2013). The UK oil and gas supply chains: An empirical analysis of adoption of sustainable measures and performance outcomes. International Journal: Production Economics. 146 (1), 501-514.

[5] Albert, O. N., Amaratunga, D., and Haigh, R. P. (2018). Environmental Policies within the Context of Compensation for Oil Spill Disaster Impacts: A Literature Synthesis. Procedia Engineering. 212 (1), 1179-1186.

[6] Audu, A., Jimoh, A., Abdulkareem, S., and Lawrence, O. (2016). Economics and Environmental Impacts of Oil Exploration and Exploitation in Nigeria. Energy Sources, Part B: Economics, Planning, and Policy. 11 (3), 251-257.

[7] Demirel-Pegg, T., and Pegg, S. (2015). Razed, Repressed and Bought off: The Demobilization of the Ogoni Protest Campaign in the Niger Delta. The Extractive Industries and Society. 2 (1), 654-663.

[8] Ndimele, E., Saba, A., Ojo, D., Ndimele, C., Anetekhai, M., and Erondu, E. 2017. Remediation of Crude Oil Spillage. In: Prince E. Ndimele The Political Ecology of Oil and Gas Activities in the Nigerian Aquatic Ecosystem. Lagos: Academic Press. 369-384.

[9] Oladipupo, S., Mudashiru, R., Oyeleke, M. and Bakere, S. (2016). Review of some Impacts of Oil Exploration and Production in Niger Delta, Nigeria. International Conference of Science, Engineering and Environmental Technology. 1 (13), 90-103.

[10] Binuomoyo, O. K. and Ogunsola, O. A. (2017). Oil Spills and the Niger Delta bloodlines: Examining the Human Tragedy. Journal of Life andPhysical Sciences. 8 (1), 8-18.

[11] Yakubu, O.H. (2017). Addressing Environmental Health Problems in Ogoniland through Implementation of

 | DOI: 10.20533/ijsed.2046.3707.2023.0063

United Nations Environment Program Recommendations: Environmental Management Strategies. Environments. 4 (28), 1-19.

[12] Yabrade, M., and Tanee, F. B. G. (2016). Assessing the Impact of Artisanal Petroleum Refining on Vegetation and Soil Quality: A Case Study of Warri South West Salt Wetland of Delta State, Nigeria. Research Journal of Environmental Toxicology. 10 (4), 205-212.

[13] Oka, N. (2017). The Spate of Environmental Degradation and its Impacts on Niger delta Communities' Sustenance. International Journal of Development and Sustainability. 6 (10), 1461-1485.

[14] Bebeteidoh, O. L., Kometa, S., Pazouki, K., and Norman, R. (2020). Sustained Impact of the Activities of Local Crude Oil Refiners on their Host Communities in Nigeria. Heliyon. 6 (1), 1-9.

[15] Elenwo, E., and Akankali, J. (2014). Environmental Policies and Strategies in Nigeria Oil and Gas Industry: Gains, Challenges and Prospects. Natural Resources. 5 (1), 884-896.

[16] Edwin, I. E., and Ugbomeh, I. L. (2017). Impact of Gas Flaring on Biodiversity in Niger Delta, Nigeria. Nigerian Journal of Science and Environment. 15 (1), 147-154.

[17] Chima, U. D., and Larinde, S. L. (2016). Deforestation and Degradation of Mangroves in the Niger Delta Region of Nigeria: Implications in A Changing Climate. 38th Annual Conference of Forestry Association of Nigeria (FAN). 38(1), pp.521-537.

[18] Roche, M., Verolme, H., Agbaegbu, C., Binninton, C., Oladipo, O., and Fischedick, M. (2019). Achieving Sustainable Development Goals in Nigeria's power sector: assessment of transition pathways. Climate Policy. 1 (1), 1-20.

[19] Pegg, T., and Pegg, S. (2015). Razed, Repressed and Bought Off: The Demobilization of the Ogoni Protest Campaign in the Niger Delta. The Extractive Industries and Society. 2 (4), 654-663.

[20] Dyner, I. (2000). Energy Modelling Platforms for Policy and Strategy Support. Journal of the Operational Research Society. 51 (2), 136-144.

[21] Zeng, Y., Cai, Y., Huang, G., and Dai, J. (2011). A Review on Optimization Modelling of Energy Systems Planning and GHG Emission Mitigation under Uncertainty. Energies. 4 (1), 1625-1656.

[22] Granado, P. C., Nieuwkoop, R. H., Kardakos, E. G., and Schaffner, C. (2018). Modelling the energy transition: A Nexus of Energy System and Economic Models. Energy Strategy Reviews. 20 (1), 229-235.

[23] Neshat, N., Amin-Naseri, M. R., and Danesh, F. (2014). Energy Models: Methods and Characteristics. Journal of Energy in South Africa. 25 (4), 101-111.

[24] Olaniyi, K. T. (2008). Decision Support Systems for Sustainable Energy Planning in A Developing Economy. PhD thesis, London South Bank University 2021). https://ethos.bl.uk/OrderDetails.do?uin=uk.bl.ethos.50671. (Access Date: 6 December 2021).

[25] The World Commission on Environment and Development. (1987). Our Common Future. New York: Oxford University Press.

[26] Giwa, S. O., Nwaokocha, C. N., Kuye, S .I., and Adama, K .O. (2019). Gas Flaring Attendant Impacts of Criteria and Particulate Pollutants: A Case of Niger Delta Region of Nigeria. Journal of King Saud University - Engineering Sciences. 31 (3), 209-217.

[27] Edwin, I. E., and Ugbomeh, I .L. (2017). Impact of Gas Flaring on Biodiversity in Niger Delta, Nigeria. Nigerian Journal of Science and Environment. 15 (1), 147-154.

[28 OGUK. (2019). Economic Report (2019). https://www .ofgem.gov.uk/sites/default/files/docs/2020/02/oguk_evide nce_economic_report_2019.pdf. (Access Date: 15 Novem -ber 2021).

[29] Simola, H., and Solanko, L. 2017. Overview of Russia's oil and gas sector. BOFIT Policy Brief. 1 (5), 1-30.

[30] Karimi, F., and Goulas, A. (2012). CCS potential in Norway – Exploring the role of flagship projects: The Mongstad and Kårstø case studies. International Journal of Sustainable Water and Environmental Systems. 4 (1).

[31] Froggatt, A., Stevens, P., and Bradley, S. (2020). Expert Perspectives on Norway's Energy Future. Energy, Environment and Resources Programme. 1 (1), 1-96.

[32] Clune, W.H., and Zehnder, A.J.B. (2018). The Three Pillars of Sustainability Framework: Approaches for Laws and Governance. Journal of Environmental Protection. 9 (1), 211-240.

[33] Adewuyi, B. A., Kiptoo, M. P., Afolayan, A. F., Amara, T., Alawode, O. I., and Senjyu, T. (2020). Challenges and prospects of Nigeria's sustainable energy transition with lessons from other countries' experiences. Energy Reports. 6 (1), 993-1009.

[34] IPCC. (2005). Carbon Dioxide Capture and Storage. Edinburgh: Cambridge University Press. pp.200-201.

[35] Cherepovitsyn, A., Chvileva, T., and Fedoseev, S. 2020. Popularization of Carbon Capture and Storage Technology in Society: Principles and Methods. International Journal of Environmental Research and Public Health. 17 (8368), 1-24.

[36] World Economic Forum. (2017). Digital Transformation Initiative. http://reports.weforum.org/digit al-transformation/wp-content/blogs.dir/94/mp/files/pages/f iles/dti-oil-and-gas-industry-white-paper.pdf. (Access Date : 6 September 2022).

 | DOI: 10.20533/ijsed.2046.3707.2023.0063

[37] Mittal, A., Slaughter, A., and Bansal V. 2017. From Bytes to Barrels the Digital Transformation in upstream oil and gas. Deloitte Insights. 1 (1), 1-25.

[38] Olaniyi, K. T. (2014). System Thinking-System Dynamics for Sustainable Energy Planning in the Developing Economy. Journal of Advancement in Engineering and Technology. 1 (1), 1-9.

[39] Ganat, T. A. O. (2020). Technical Guidance for Petroleum Exploration and Production Plans. Switzerland: Springer. 1-12.

[40] Chenault, R. L. (2020). Oil and gas field exploitation. Access Science. 1 (1), 1-1.

[41] Worldometer. (2021). Oil left in the world. https://www.worldometers.info/oil/. (Access Date: 6 September 2022).

[42] Oladipupo, S. O., Mudashiru, R. B., Oyeleke, M .O., and Bakare, S. B. (2016). Review of some Impacts of Oil Exploration and Production in Niger Delta, Nigeria. International Conference of Science, Engineering and Environmental. 1 (13), 90-103.

[43] Onyena, A. P., and Sam, K. (2020). A review of the Threat of Oil Exploitation to Mangrove Ecosystem: Insights from Niger Delta, Nigeria. Global Ecology and Conservation. 22 (1), 1-12.

[44] Wilson, R. (2017). Impacts of Climate Change on Mangrove Ecosystems in the Coastal and Marine Environments of Caribbean Small Island Developing States (SIDS). Caribbean Marine Climate Change Report Card: Science Review. 1 (1), 60-82.

[45] Elekwachi, W., Nwankwoala, H. O., Ocheje, J. F., and Onyishi, C. J. (2019). Oil Spill Incidents and Wetlands Loss in Niger Delta: Implication for Sustainable Development Goals. International Journal of Environment and Pollution Research. 7 (1), 1-20.

[46] Akpokodje, J., and Salau, S. (2015). Oil pollution and agricultural productivity in the Niger Delta of Nigeria. Environmental Economic. 6 (4), 68-75.

[47] World Bank Group. (2020). Global Gas Flaring Tracker Report. https://pubdocs.worldbank.org/en/503141595343850009/WB-GGFR-Report-July2020. pdf. (Access Date: 15 September 2022).

[48] Nwosisi, M.C., Oguntoke, O., Taiwo, A.M., Agbozu, I.E. and Noragbon, E.J. (2021). Spatial patterns of gas flaring stations and the risk to the respiratory and dermal health of residents of the Niger Delta, Nigeria. Scientific African. 12 (1), 1-10.

[49] Mafimisebi, O. P., and Ogbonna, O. C. (2016). Enviro -nmental Risk of Gas Flaring in Nigeria: Lessons from Chevron Nigeria and Ilaje Crisis. Journal of Environment and Earth Science. 6 (3), 180-204.

[50] Okotie, S., Ogbarode, N.O. And Ikporo, B. (2017). The Oil and Gas Industry and the Nigerian Environment. In: Ndimele, E. The Political Ecology of Oil and Gas Activities in the Nigerian Aquatic Ecosystem. Lagos: Academic Press. 47-69. ISBN 978-0128093993.

[51] Yahaya, J. B., and Zango, A. M. (2020). Niger-Delta Crisis and Participatory Conflict Management Approach. Global Scientific Journals. 8 (1), 898-926.

 | DOI: 10.20533/ijsed.2046.3707.2023.0063