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EVALUATING THE ENVIRONMENTAL ASPECTS OF PETROLEUM PRODUCTION FACILITIES IN THE NIGER DELTA, NIGERIA

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ABSTRACT

*The oil and gas industry plays a vast role in the socio-economic development and political advancement of Nigeria. Despite the numerous benefits, a lot of environmental aspects are associated with petroleum and gas production facilities in the Niger Delta Region. Result of field measurement around an oil and gas facility in Rivers State indicated that high concentrations of CH_4, SO_2, NO_2, NH_3 and H_2S up to 50,000ppm, 5ppm, 5ppn, 10ppm and 506ppm respectively. Field reports and statistical data indicated an estimated **350,107.43** barrels of petroleum were spilled into the Niger Delta environment between 2010 and 2019; the highest volume of **157,098.96 barrels (45%)** spilled in Rives State, followed by Delta State with **79,375.65 barrels (23%)** and Bayelsa State with **63,123.19 barrels (18%)**; crude oil theft accounting for **47%,** sabotage accounting for **35%,** while operational, equipment failures and mystery spills accounted for **18%** of total oil spilled. Approximately, **1.42 billion** million standard cubic feet (mscf) of natural gas was flared in selected 7 states in Nigeria between 2012 and 2019; **75.7 million** tonnes of CO_2 are emitted into the atmosphere; an estimate of **4. 94billion** US Dollars is lost in 6 states between 2012 and 2019 due to gas flaring; approximately **141.6** thousand Giga Watt-hour of electricity is also lost. Enormous volumes of hazardous drilling waste/chemicals and wastewater effluent are discharged into the environment. The air, land, water resources, both terrestrial and aquatic plants and animals in the Niger Delta are adversely devastated. The ecological systems, public health, agriculture, natural resources and economic livelihoods have been significantly degraded. Hence, the study highlighted the need for all stakeholders, particularly the government and multinational oil and gas companies to quickly intervene and take urgent measures that save the Niger Delta environment and its inhabitants from imminent destruction.*

Keywords: Environmental consequences, Oil spills, Gas flaring, Hazardous waste, Ecological systems, Sources of livelihood, and Oil-bearing communities.

1.0 INTRODUCTION

The Niger Delta consists of nine states namely: - Abia, Akwa Ibom, Bayelsa, Cross River, Delta, Edo, Ondo, Imo and Rivers (Ite et al., 2013) as shown in Figure 1. Petroleum was discovered in the Niger Delta region of Nigeria in 1956 and commercially produced in 1958 (Ayuba, 2012; Raji and Abejide, 2013), and since then it has become the main sustenance of the economy of Nigeria (Ibeawuchi, 2016). Notwithstanding the numerous benefits of the petroleum industry to the economy of Nigeria, petroleum production activities have greatly interfered with the ecological balance of nature in the Niger Delta due to large scale impacts on the environment (Ayuba, 2012; Musa, 2017). Land, water and air in the Niger Delta have been polluted as a result of exploration and production of oil and gas in the Niger Delta (Ayuba, 2012). The Niger Delta environment is being incessantly degraded as a result of oil spills, gas flaring, and discharge of hazardous waste into the environment (Ayuba, 2012). Oil and gas activities in the region have grossly interfered with the legitimate and economic uses of the environment by the oil and gas bearing communities of the Niger Delta (Ayuba, 2012; Brown & Tari, 2015). Breathing polluted air and drinking from polluted sources of water have affected the health of the people from the host communities (Ayuba, 2012).

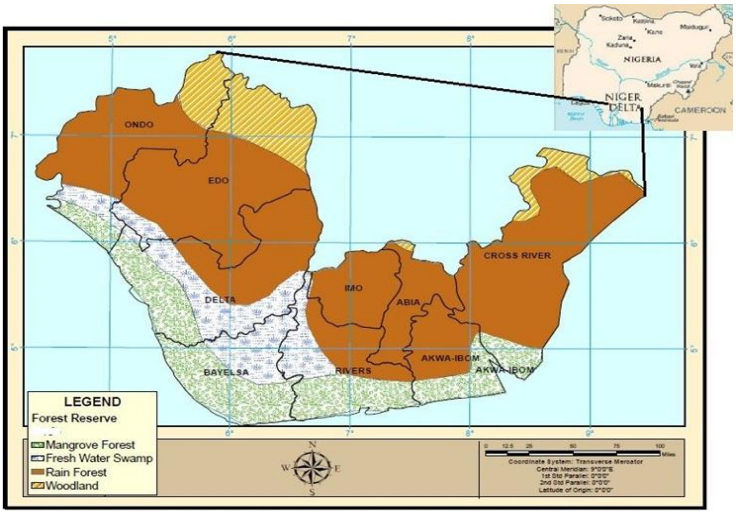

Fig. 1: Map of Nigeria showing the Niger Delta Region

2.0 A BRIEF DESCRIPTION OF THE OIL AND GAS INDUSTRY IN NIGERIA

The Oil and gas industry is divided into upstream and downstream operations (Barclays, 2015) as shown in Figure 2. Upstream operations involve exploration which includes seismic survey, exploratory drilling; oil field development drilling, production and transportation. The downstream operations involve refining (Prioleau, 2003), petrochemicals, distribution of products and retail of refined petroleum products (Figure 2). Oil and gas activities take place either onshore (terrestrial) or offshore (marine) or a combination of both.

This paper therefore, attempts to evaluate the environmental aspects of petroleum production facilities in the Niger Delta region of Nigeria. The paper ensembles significant field data, reported data, scientific reports and information on the various environmental issues associated with oil and gas operations in the Niger Delta. It took performs an exhaustive analysis of available data on environmental discharges from multiple sources, investigates a number of relevant environmental aspects and analyses current and past environmental data. It proffers possible mitigation measures and best practices to achieve a sustainable environment in the Niger Delta region. The paper is expected to be useful to operators of the petroleum industry, environmental managers, policy makers and all the stakeholders in the petroleum industry in Nigeria.

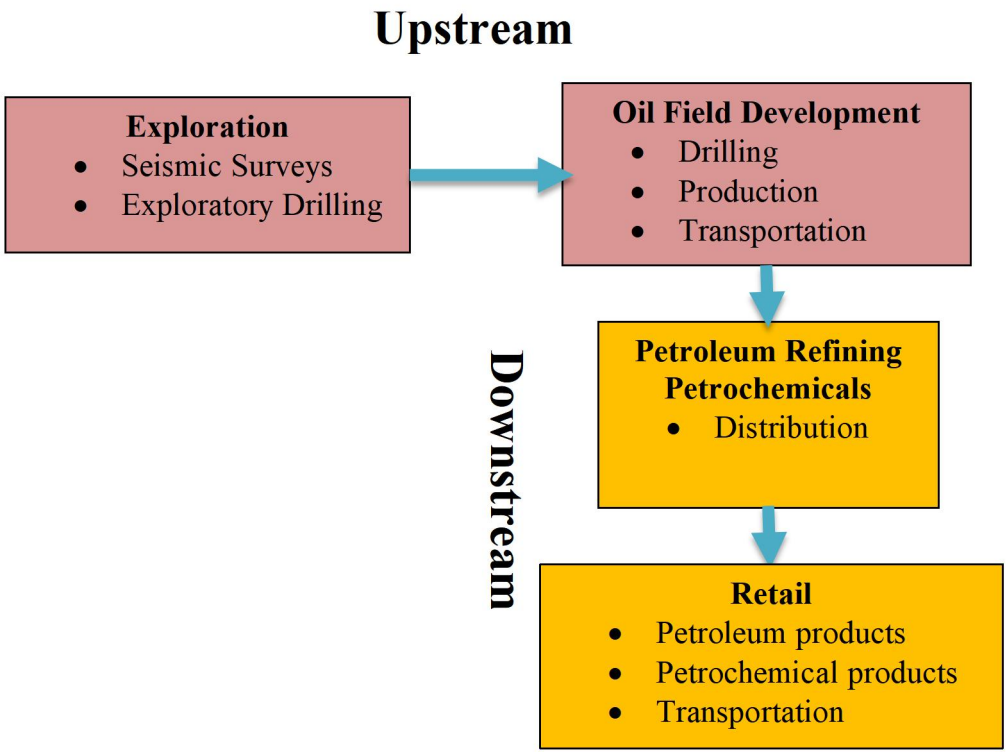

Fig. 2: Stages in Oil and Gas Production Process

3.0 METHODOLOGY

The paper employed quantitative empirical research approach using empirical evidences based on field data, observations and reviews of previous studies. The oil spill incident data were obtained using Oil Spill Monitor (NOSM) developed by the National Oil Spill Detection and Response Agency (NOSDRA). Part of the oil spill data were also obtained from field reports by the Shell Petroleum Development Company of Nigeria Limited (SPDC), an operator of SPDC Joint Venture (SPDC-JV) facilities in the Niger Delta. The data are contained in the Joint

Investigation Visit report (JIV) produced by the Joint Investigation Team (JIT). The data were aggregated, processed and analyzed as presented in this study. Noise levels were measured at some locations around an oil and gas facility in Rivers. The noise measurement was conducted using a TES digital sound level meter (Model 1352H). The continuous equivalent noise levels (Leq) for each location were compared with the National Environmental Standards and Regulatory Enforcement Agency [NESREA] (2009) Leq limit of 70dBA.

4.0 RESULTS AND DISCUSSION

4.1 Emissions to Atmosphere

The average concentrations of air pollutants emissions measured around a typical oil and gas production facility in the Niger Delta during field monitoring are presented in Table 1. The concentration of CH_4, SO_2, NO_2, NH_3 and H_2S were up to 50,000ppm, 5ppm, 5ppn, 10ppm and 506ppm respectively. The values of SO_2 and NO_2 far exceeded exceed FMEnv and DPR stipulated permissible limits as shown in Table 1. According to Prioleau, (2003), atmospheric emissions are associated with exploration and production drilling, refining activities and road transportation of products. Air emissions emanate from purging gases, venting and flaring of gases (E&P Forum/UNEP, 1997; Raji and Abejide, 2013), combustion processes, site clearing, constructions, vehicular and plant exhaust and fugitive emissions from process equipment, loading operation and storage tanks (Prioleau, 2003, USEPA, 2008; Barclays, 2015). Primary gaseous pollutants emitted into the atmosphere include hydrogen Sulphide (H_2S), nitrogen oxides (NO_x), carbon monoxide (CO), sulphur oxides (SO_x), ammonia (NH_3) and methane (CH_4). Methane is a greenhouse gas (GHG) that contribute to global warming and climate change. It is evident from the result shown in Table 4 that oil and gas facility is a major contributed to global warming in the Niger Delta. A similar study conducted by Ugbebor and Yorkor (2018) on air quality around selected oil and gas facilities indicates severe air pollution around the facilities and moderate air pollution around the host communities in the Niger Delta region.

Table 1: Summary of average air pollutants measured around oil and gas facility in Rivers State

Station	SO_2 (ppm)	NO_2 (ppm)	CO (ppm)	H_2S (ppm)	CH_4 (ppm)	NH_3 (ppm)
ST01	1.0	1.0	1.0	50.0	400.0	ND
ST02	1.0	1.0	3.0	135.0	ND	ND
ST03	2.0	2.0	3.0	63.0	500.0	ND

ST04	1.0	0.0	1.0	506.0	12,100	ND
ST05	5.0	5.0	3.0	436.0	23,100	1.0
ST06	2.0	2.0	3.0	101.0	2,200	1.0
ST07	ND	ND	1.0	142	50,000	ND
ST08	2.0	2.0	ND	18	46,000	8.8
ST09	ND	ND	1.0	121	ND	10.0
ST10	ND	ND	1.0	10.0	ND	ND
FMenv Limit	**0.1**	**0.06**	**10**	**-**	**-**	**-**
DPR Limit	**0.15**	**0**	**10**	**-**	**-**	**-**

(Field Survey, 2019) ND = not detected

ST1 to ST10 are monitoring locations around a petroleum production facility in Rivers State.

4.2 Gas Flaring

Collected data indicate that 39.91 billion mscf of gas was produced in Abia, Akwa Ibom, Bayelsa, Delta, Imo and Rivers between 2001 and 2017 out of which 4.69 billion mscf (12%) was sold and 10.18 billion mscf (26%) was flared as shown in Figure 3. Gas flaring constitutes a major source of air pollution associated with petroleum production facilities in the Niger Delta (Raji and Abejide, 2013). Nigeria is ranked amongst the largest gas flaring nation in the world (Okeke et al., 2016; Aregbe, 2017). Figure 4 shows spatial gas flare locations/sites in the Niger Delta as digitized from NOSDRA Gas Flare Tracker. According to the Federal Government, Nigeria has about 178 gas flaring sites as at 2017, however, NOSDRA Gas Flare Tracker put the figure at 222 (BugiT, 2018). According to NOSDRA "useful gas worth millions of dollars is flared every day in the Niger Delta" (https://nosdra.gasflaretracker.ng/#training). Statistical data (Table 2) indicates that a total estimate of **1.42billion Mscf** of gas was flared in Abia, Akwa Ibom, Bayelsa, Delta, Edo, Imo and Rivers states between 2012 and 2019 (NOSDRA, 2019) with the emission of **75.7 million** tonnes of carbon dioxide into the atmosphere. This amount of flared gas is valued at about **4. 93billion US Dollars** and capable of generating **141.6** thousand Giga Watt-hour of electricity**.** Gas flare statistics in selected seven states in the Niger Delta between 2012 and 2019 is presented in Table 2. Trends in gas faring in the seven states (Figure 5) show a relatively constant trend in Abia, Edo and Rivers States; increasing trend in Bayelsa and Delta States and a decreasing trend in Imo State. Example of gas flaring in the Niger Delta is shown in Figure 6.

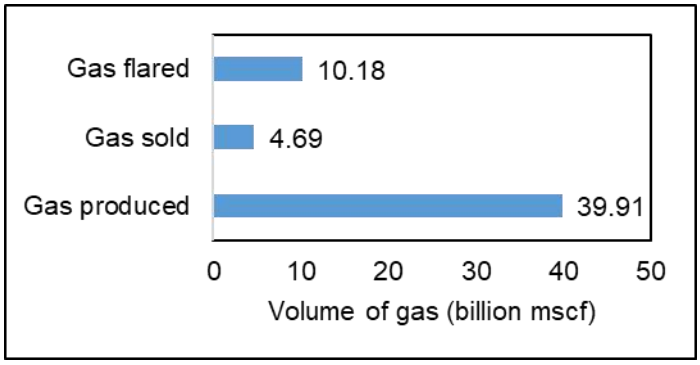

Fig. 3: Gas produced versus gas sold and flared (2001 – 2019) Source: DPR, 2017 Oil and Gas Annual Report, Table 53, page 82.

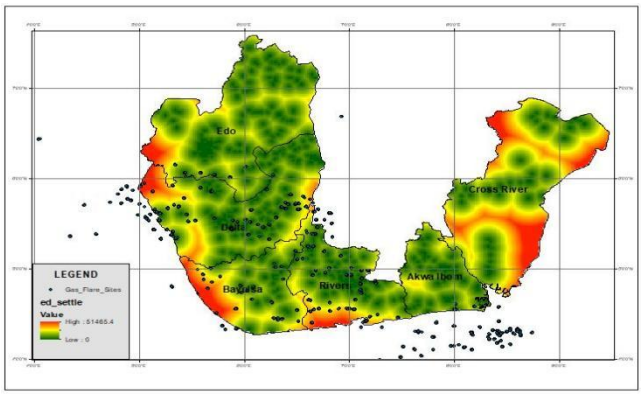

Fig. 4: Digitized spatial gas flare sites in the Niger Delta

Table 2: Gas Flare statistics in selected Niger Delta states between 2012 and 2019

State	Gas flared (million mscf)	CO_2 Emissions (million Tonnes)	Gas value (million USD)	PGP (thousand GWh)
Abia	4.4	0.2363	15.6	0.4448
Akwa Ibom	37.8	2.6	171.5	3.8
Bayelsa	249.0	13.2	871.3	24.9
Delta	491.9	26.1	1700	49.2
Edo	124.8	6.6	436.6	12.5
Imo	69.0	3.7	241.4	6.9
Rivers	438.4	23.3	1500	43.84
Total	**1, 415.3**	**75.7**	**4, 936.4**	**141.6**
Average	**202.19**	**10.82**	**705.20**	**20.23**

Mscf = Million standard cubic feet; USD, United States Dollars; PGP = power generation potential; GWh = Giga Watt-hour. Source: NOSDRA (2023).

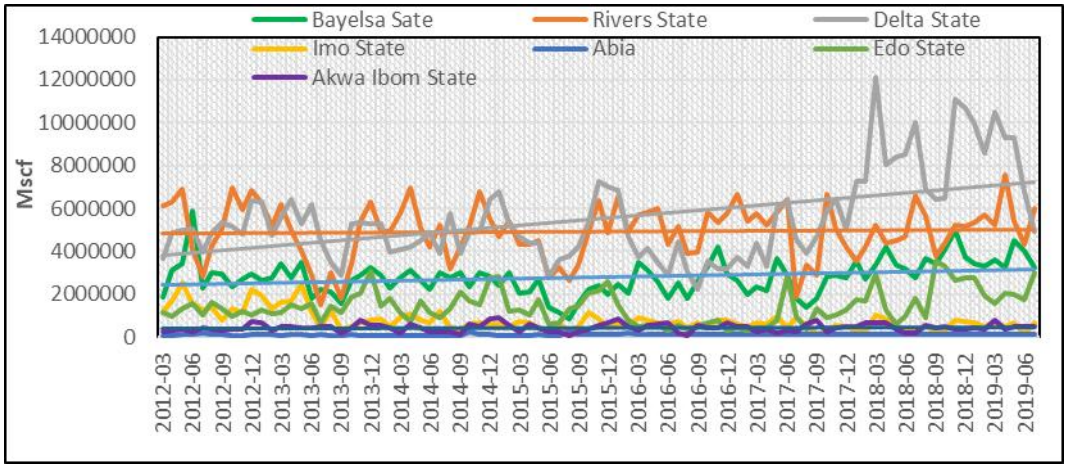

Fig. 5: Trends in gas faring in selected Niger Delta states the between 2012 and 2019

Fig. 6: Gas Flaring in the Niger Delta

NOSDRA Gas flare tracker (2023)

4.3 Noise pollution

Noise levels measured around an oil and gas facility in Rivers State are shown in Figures 4. Noise levels measured around the oil and gas facility range from 70.8 dBA at location ST01 to 100.5 dBA at location ST05. The Leq values were between 82.3 dBA at location ST07 and 98.4 at location ST05. The noise level exceedance factor ranges between 1.1 and 1.4 with percentage exceedance ranging from 13.6 % to 40.6 %. The result (shown in Table 3) shows that the average Leq values exceed NESREA permissible limit of 70dBA at all the locations around the oil and gas facility. This finding clearly shows that noise production is another aspect associated with the oil and gas operations in the Niger Delta. Oil and gas exploration, drilling, processing and distribution typically involve a vast array of equipment and processes, all of which combine to create high levels of noise emissions. Primary sources of noise during the drilling/development phase are bulldozers, drill rigs, and diesel engines. Other sources of noise include vehicular traffic and compressors for blasting activities. The highest noise levels occur from drilling and flaring of gas (MEC, 2010). Noise from drilling has been measured as

115 dBA (MEC, 2010). Exploratory wells that end up becoming production wells continue to generate noise during the production phase (MEC, 2010). The major noise sources from production operations are flow of oil, steam and gas through pipes, valves. This noise level is estimated to range between 80 - 90 dBA (Mandira, 2010).

Table 3: Summary of noise levels measured around oil and gas facility in Rivers State

Station	Noise values (dBA)				
	Min	Max	Leq	Exceedance Index	%Exceedance
ST01	70.8	88.9	85.6	1.2	22.3
ST02	77.2	1001.1	91.7	1.3	31.0
ST03	72.1	88.3	79.5	1.1	13.6
ST04	75.4	99.6	88.8	1.3	26.9
ST05	85.9	100.5	98.4	1.4	40.6
ST06	73.8	96.6	90.6	1.3	29.4
ST07	71.4	86.5	82.3	1.2	17.6
ST08	83.7	94.3	87.1	1.2	24.4
ST09	86.5	100.2	93.8	1.3	34.0
ST10	78.1	99.1	92.9	1.3	32.7
NESREA limit			70		

4.4 Thermal pollution

Main sources of thermal pollution are heat waves from flare stacks, combustion heaters, thermal processing, crude oil production, petrochemical production and petroleum refining processes (Barclays, 2015). These heat waves cause an increase in the atmospheric temperature contributing to global warming, heat stress and skin diseases.

4.5 Discharges to water Resources

Discharge to water resources is another aspect associated with oil and gas production facilities in the Niger Delta region. The main discharged waste stream includes sanitary wastes, sewerage, produced water, process effluent, well treatment chemicals, cooling water, drilling cuttings and muds as well as oil leakages and spills. The discharge of these waste streams into water bodies contribute immensely to water pollution in the Niger Delta. Drilling muds or fluids and drilling cuttings are produced during oil exploratory drilling (Ugboma, 2015; Musa, 2017; Akpoghelie et al., 2021), while produced water effluents are generated during production

operations. These waste streams, particularly oil-based drilling muds and oily cuttings, contain toxic chemicals and heavy metals (Ba, Cd, Zn, Pb), which affect aquatic life and species diversity (Ugboma, 2015). Ocean discharges of water-based and oil-based muds and cuttings have been shown to affect benthic organisms due to high levels of hydrocarbons and toxicity. Drilling muds and cuttings also contain elevated levels of inorganic salt and pH which may negatively affect fresh water sources. Produced water from production operations contains varying quantity of heavy metals, toxic chemicals, inorganic salts and poly aromatic hydrocarbons (PAH), which pollutes surface water and groundwater aquifers when discharged into the environment. These pose potential harm to human health, and aquatic life (fauna and flora) (Ugboma, 2015).

4.6 Contamination of Land

Land degradation is another major environmental aspect found associated with oil and gas production facilities in the Niger Delta. Principal activities associated with land contamination are seismic operations, exploratory drilling, constriction of access roads, laying of pipelines and transportation (Ugboma, 2015). Seismic activities, construction of access roads, pipeline laying result in land clearance/disturbance, removal of vegetation, which cause land erosion, landscape scarring and localized land subsidence. Oil leakages and spillages from pipelines, production operations result in the pollution of land and subsequently the contamination of farmlands in the Niger Delta.

4.7 Oil spillages in the Niger Delta

Oil spillages is a major environmental aspect of oil and gas production facilities in the Niger Delta**,** which contaminate air, water, land and the ecosystem (Musa, 2017). Oil spillages may occur during production operations and pipeline explosion (Musa, 2017). Oil spill sites in the Niger Delta are shown in Figure 7. Data obtained using NOSDRA Oil Spill Monitor indicate that a total of 7,788 oil spill incidents occurred in selected seven Niger Delta states of Abia, Akwa Ibom, Bayelsa, Delta, Edo, Imo and Rivers between 2010 and 2019 (Table 4). The highest oil spills occurred in Bayelsa state during this period followed by Rivers and Delta States. Trend in yearly oil spill incidents in the Niger Delta is shown in Figure 8, while yearly total and average volume spilled oil between 2010 and 2019 are shown in Figure 9. During this period, a total of 350,107.43 barrels of crude oil were spilled with the highest volume of 157,098.96 barrels (45%) spilled in Rives State, followed by Delta State with 79,375.65 barrels (23%) and Bayelsa State with 63,123.19 barrels (18%) as shown in Table 4. Data obtained on causes of oil spillages (NOSDRA, 2019) as shown in Figure 10 indicated that crude oil theft is

the major cause of oil spills in the Niger Delta accounting for 47% of total oil spilled, followed by sabotage with 35% and operational failures with 14%, while equipment failure and mystery each accounted for 2% of oil spills in the Niger Delta. This finding corroborated the works by Akpoghelie et al. (2021) and Bello and Nwaeke (2023). Also, it was found that oil spills impacted more on water resources (water bodies) including swamps, accounting for 68% compared to land environment (32%) as shown in Figure 11. This corroborated the work of Akpoghelie et al. (2021).

Table 4: Oil spilled in Some Niger Delta States, 2010 – 2019

State	Incident	Barrels	Percentage (%)
Abia	115	7638.67	2.0
Akwa Ibom	620	31433.08	9.0
Bayelsa	2829	63123.19	18.0
Delta	1113	79375.65	22.0
Edo	141	2342.12	1.0
Imo	164	9095.76	3.0
Rivers	2806	157098.96	45.0
Total	**7788**	**350107.43**	**100**
Average	**1113**	**50015**	

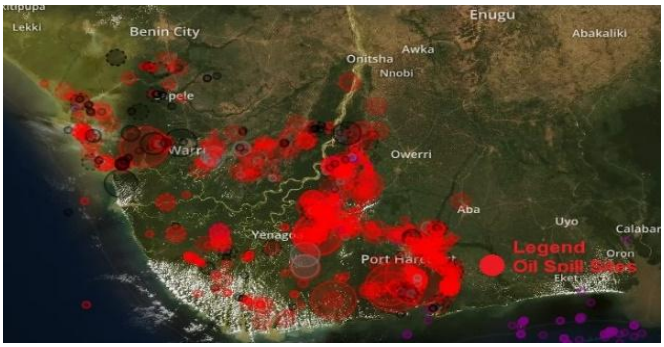

Fig. 7: Oil Spill sites in the Niger Delta source: NOSDRA Oil Spill Monitor, 2019).

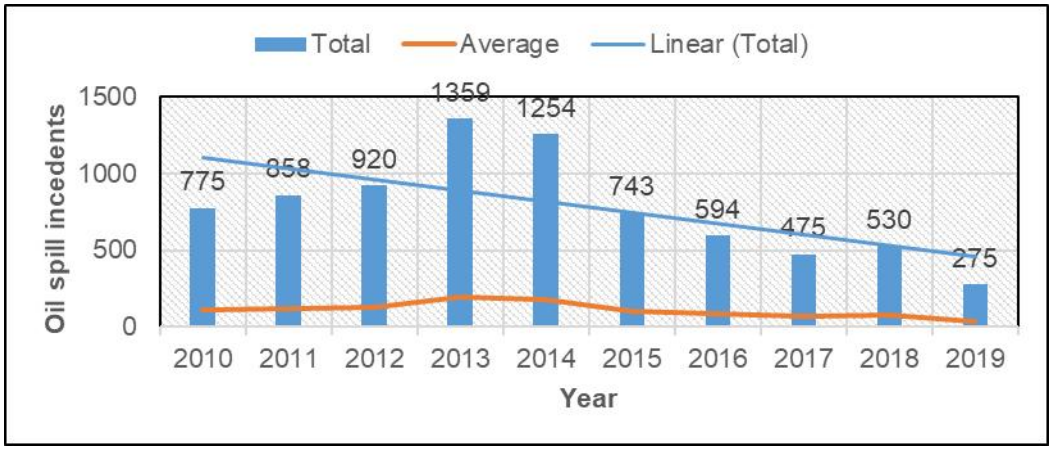

Fig. 8: Trend in Yearly oil Spill Incidents in the Niger Delta, 2010 – 2019

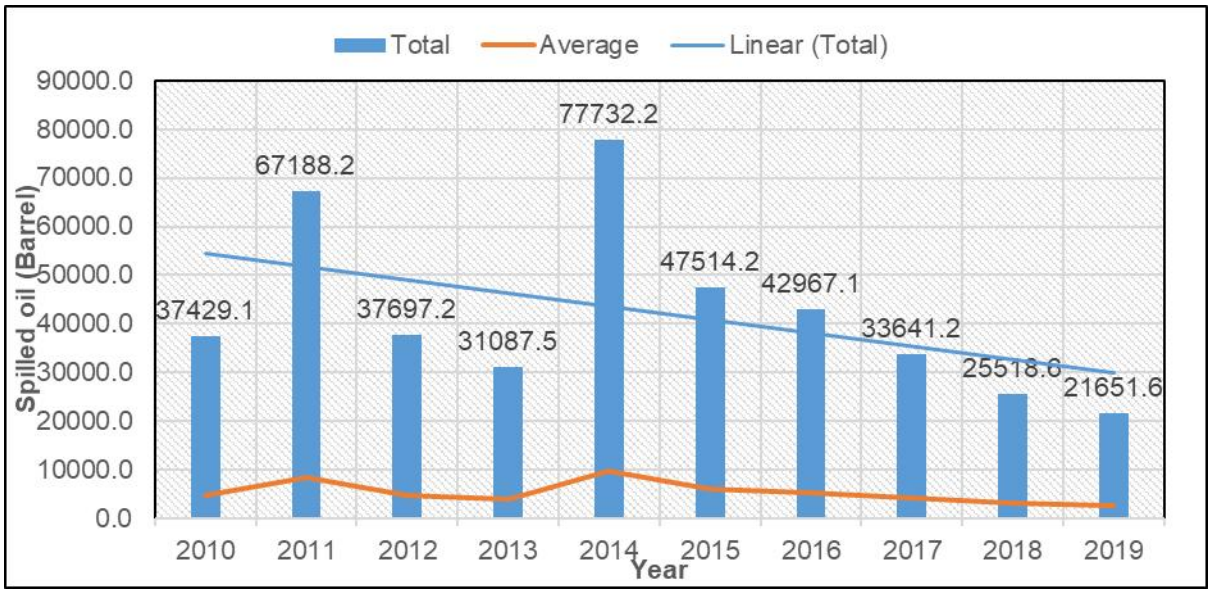

Fig. 9: Yearly Total and Average Volume spilled, 2010 – 2019

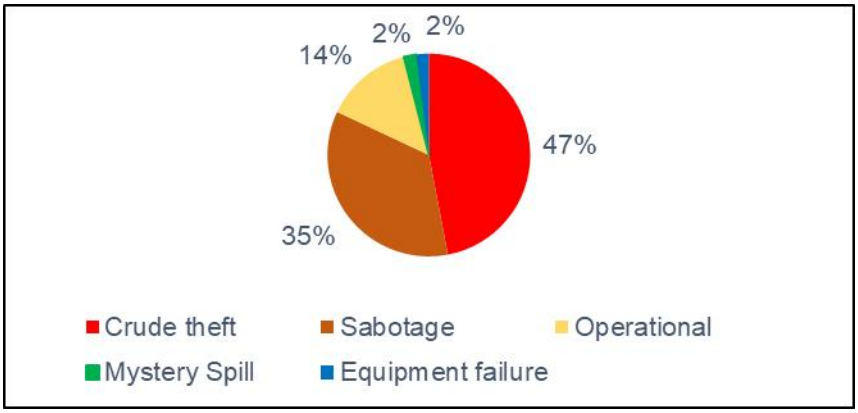

Fig. 10: Causes of oil spills in Nigeria, 2010 - 2019

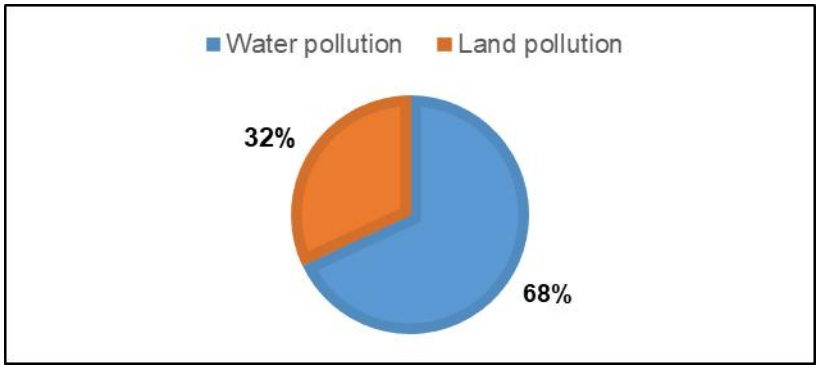

Fig. 11: Percentage impact on Land and Water Resources, 2010 – 2019

4.8 Waste Generation

Oil and gas operations generate enormous amount of wastes, especially hazardous waste. Seismic operations generate domestic, explosive, sewage, and solid wastes such as electric cables (E&P Forum, 1993; E&P Forum/UNEP, 1997; SEPA, 2008; Barclays, 2015). Exploratory drilling generates drilling chemicals, drilling muds, drilling cuttings, cementing waste, process wastewater, solid and hazardous wastes (SEPA, 2008; Barclays, 2015). Construction activities produce solid waste, solvents, waste oils, excess paints, excess construction materials and sewage Well development and production generate produced water, flare and vent gas, production chemicals, work over wastes, tank and pit bottoms (E&P Forum/UNEP, 1997; SEPA, 2008; Barclays, 2015). Maintenance cut across all phases of exploration and production processes and wastes such as used batteries, tyres, used lubricants, paints, solvents, contaminated soil, scrap parts and metals are generated, while decommissioning and abandonment generate waste materials, used plant equipment, contaminated soil and sludge (E&P Forum, 1993; E&P Forum/UNEP, 1997; SEPA, 2008; Barclays, 2015).

5.0 CONSEQUENCES OF ENVIRONMENTAL ASPECTS OF OIL AND GAS PRODUCTION FACILITIES IN THE NIGER DELTA

The identified environmental aspects of the various operational sources of oil and gas production facilities have the potential to impacts several components of the biosphere in the Niger Delta if not properly controlled using Best Available Technology and Operational Practices (BATOP). Some of the identified evidential consequences of environmental aspects associated with oil and gas production facilities in the Niger Delta include destruction of economic activities and property in the Niger Delta (Ayuba, 2012; Raji & Abejide, 2013; Musa, 2017; Osuagwu & Eseoghene, 2018), air pollution, noise pollution, greenhouse gas emissions,

acid rain, ground and surface water pollution, land contamination and degradation, light pollution and heat waves, ecosystem damage and biodiversity depletion (Masu, 2017; Yakubu, 2017; Ugbebor & Yorkor, 2018), flood and erosion, impact on human and animal health and crises and instability in the Niger Delta (Oluniyi, 2017). These are some of the plethora of environmental impacts associated with oil and gas production facilities which the people of the Niger Delta have to contend with on a daily basis.

6.0 CONCLUSION

The paper has shown that gas flaring, oil spills, discharges to water resources, contamination of land and waste generation are some of the major environmental aspects associated with oil and gas production facilities in the Niger Delta. The study showed that an estimated **350,107.43** barrels of petroleum were spilled into the Niger Delta environment between 2010 and 2019. Approximately, **1.42 billion** million standard cubic feet (mscf) of natural gas was flared in the same period, with about **75.7 million** tonnes of CO_2 are emitted into the atmosphere. The study further revealed that an estimate of **4. 94billion** US Dollars is lost between 2012 and 2019 due to gas flaring, amounting to **141.6** thousand Giga Watt-hour loss of electricity. Crude oil theft (**47%),** sabotage (35**%),** operational, equipment failures and mystery spills (**18%)** were identified causes of oil spills in the Niger Delta.

The environmental aspects arising from oil and gas exploration and production activities have greatly devastated the environment of the Niger Delta with adverse consequences of air pollution, pollution of land and water resources, destruction of the ecosystem, biodiversity depletion, diverse kinds of diseases, crises and abject poverty in the region. Environmental degradation has contributed to the decline in sources of livelihood (like fisheries, arable land other businesses that dominated the traditional economy of the region.

The study highlighted the need for operators of the oil and gas industry in Nigeria to adopt a multidimensional approach in mitigating the environmental problems in the Niger Delta. This can be done through right environmental policies, compliance with relevant national and international environmental laws, regulations, standards, environmental stewardship, minimizing operational footprint, use of best available technologies and operational procedures (BATOP).

The study advocates for the establishment of community/stakeholder relations management programme to interface between oil bearing communities and multinational oil and gas companies in the region. Therefore, there is the need for a paradigm shift by all stakeholders, including government intervention agencies, the multinational oil companies (MNOCs) and the citizens at large.

7.0 RECOMMENDATIONS

Mitigating measures aimed at ameliorating environmental problems in the Niger Delta requires a multidimensional approach. Hence, the following recommended actions and approaches as a way forward become imperative:

i. The multinational oil companies should adopt the concept of sustainable development in the oil and gas industry, with the use of modern and best available technologies to prevent incidents of oil spills.
ii. There is the need for operators in the oil and gas industry to invest more in the energy industry.
iii. Cutting off available markets for stolen crude can help reduce cases of crude oil theft in the Region.
iv. The issue of high rate of unemployment and poverty in the Niger Delta should be adequately addressed, especially by the multinational oil and gas companies and Federal Government of Nigeria.
v. State and Federal governments as well as private investors should as a matter of fact invest in the building modular refineries. This will not only fetch employment for the restive youths in the region, but will also help in curbing cases of crude oil theft.
vi. Multinational oil and gas companies need to establish community/stakeholder relations management programme to interface with oil-bearing communities.
vii. The Petroleum Industry Bill (PIB) should be implemented with all honesty, devoid of political interference.
viii. Government should leverage on the availability of innovative technologies, particular artificial intelligence (AI) and commit financial resources to enhance this innovative transformation in the oil and gas industry.
ix. Need to diversify the economy of the country to reduce over dependent on oil as a major source of income.
x. Shift from Oil and Gas to renewable energy production and improve access to renewable energy sources for businesses and households in the region.

Competing Interests:
Authors have declared that no competing interests exist.

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9.0 APPENDIX

Destruction of mangrove forest in Bodo, Ogoni, Niger Delta (Field snapshot)

Oil Spills in Bayelsa State, Niger Delta (JIV Report, 2015)

Fish kills, Musa (2017)

Oil Spill Impact on the Environment, Delta State, Niger Delta (JIV report, 2015)

Destruction of the Ecosystem, Belema, Rivers State, Niger Delta (JIV Report, 2015)

Light pollution: Light reflection on surface water

(NOSDRA Gas flare tracker (2023)