Proceedings of the 37th iSTEAMS Cross-Border Conference – Accra Ghana 2023
Series 37, Volume No 2

Faculty of Computational Sciences & Informatics - Academic City University College, Accra, Ghana
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37th International Science Technology Education Arts Management
& Social Sciences (iSTEAMS) Cross-Border Conference - Accra Ghana 2023

# The Application of Systems Thinking System Dynamics (ST/SD) Tool to Analyse Oil and Gas Operations Environmental Sustainability Issues in the Niger Delta Region of Nigeria

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## ABSTRACT

This study focused on the application of the Systems Thinking System Dynamics (ST/SD) tool to analyse oil and gas environmental sustainability issues in the Niger Delta region (NDR) in Nigeria. 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 Global South with regulations 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. In total, fossil fuels accounted for up to 85% of global energy production the same year. 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 and business models to reduce the impacts on the environment. The study adopted Rentier State, Resource Curse and Stakeholder theories. This study adopted a qualitative approach, data was collected from secondary sources and analysed. To fully understand the issues in the NDR, the study employed the Systems Thinking System Dynamics (ST/SD) methodological tool to uncover the operational practices associated with oil and gas operations in the NDR. It is a holistic approach with elements of feedbacks and delays which enhance the understanding of a complex situation such as the NDR in Nigeria.

**Keywords**: Environmental Sustainability, Oil and Gas Operations, Systems Thinking System Dynamics (ST/SD), Niger Delta Region (Nigeria).

**Proceedings Citation Format**
Rasaki T. James, Titus K. Olaniyi & Posi Olatubosun (2023): The Application of Systems Thinking System Dynamics (ST/SD) Tool to Analyse Oil and Gas Operations Environmental Sustainability Issues in the Niger Delta Region of Nigeria. Proceedings of the 37th iSTEAMS Multidisciplinary Cross-Border Conference. 30th October – 1st November, 2023. Academic City University College, Accra, Ghana. Pp 1-16. .dx.doi.org/10.22624/AIMS/ACCRACROSSBORDER2023V2P1

## 1. BACKGROUND TO THE 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 (Doric and Dimovski, 2018) as shown in Figure 1.1. The exploration and production of oil and gas continue to be a priority in producer countries of the Global South with regulations being implemented to enhance the sustainability of the industry (Obeng-Odoom, 2018; Doric and Dimovski, 2018). 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 (IEA, 2020).

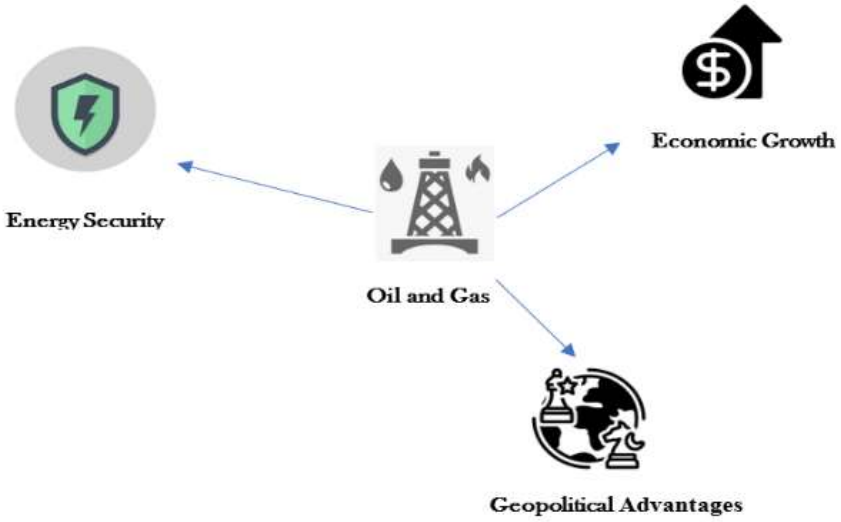


Figure 1.1 National Importance of Oil and Gas Operations (Source: Author's)

Figure 1.1 demonstrates the importance of oil and gas to the nations of the world; playing a key role in energy security, economic growth and enhancing geopolitical advantages.

Most oil and gas producing countries of the Global North such as the United Kingdom are implementing sustainable measures in energy production (Yusuf et al., 2014). However, on a large scale, the 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 focus of this study, oil spillages regularly occur; as of 2018, there had been up to 9500 incidences of an oil spill in a decade. Annually, on average, about 115,000 barrels (equivalent to about $5 million worth) are spilt into the environment (Ndimele, et al., 2017).

The Niger Delta is arguably the region with the highest volume of gas flaring globally, with a daily average of 800,000m3 of gas flare (Adekola, Fischbacher-Smith and Fischbacher-Smith, 2017). This causes long term diseases such as cancer and breathing difficulties, it also increases the risk of climate change and global warming. 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.

The report titled ''Our Common future'' chaired by Brundtland (1987) emphasises meeting the needs of the present generation without affecting the ability to meet the needs of future generations. It argued that economic development could be achieved whilst protecting the environment.

In tackling climate change, the 2015 COP21 Paris agreement called for member countries to implement measures that would keep global temperature below 2 degrees C (Gao, Gao and Zhang, 2017). In 2015, the member states of the United Nations adopted the 2030 agenda for sustainable development, which includes acting on 17 Sustainable Development Goals (United Nations, 2020). Relating this to the Niger Delta scenario, points 3 (good health and well-being), 7 (affordable and clean energy) and 13 (climate action) must be addressed in the management of oil and gas operations in this region which result in environmental sustainability issues. Therefore these (Brundtland report, COP 21 and UNSDGs) have formed the basis for environmental sustainability in energy planning and development in recent times. It is against this backdrop that this research applies the Systems Thinking System Dynamics tool analyse environmental sustainability issues resulting from oil and gas operations in the NDR.

### 1.1 Statement of Problem

Oil and gas operations in the Nigeria Niger Delta region have resulted in environmental degradation through high levels of oil spillages and gas flaring (Binuomoyo and Ogunsola, 2017). 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 (Yakubu, 2017). The non-standard practices of local refiners result in oil spillages; wiping off more than 50,000 acres of mangrove forest (Yabrade and Tanee, 2016; Oka, 2017; Bebeteidoh et al, 2020). 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 (Yakubu, 2017; Temilola et al, 2020). 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 (Elenwo and Ankali 2014; Edwin and Ugbomeh, 2017).

The unabated environmental degradation in the NDR has negatively affected the means of livelihood (fishing and farming) of the people (Chima and Larinde, 2016) 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 (Elenwo and Ankali 2014; Albert, Amaratunga and Haigh, 2018), caused majorly by administrative bottlenecks and corruption (Mantu, 2019; Roche et.al., 2019).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(Pegg and Pegg, 2015; Mai-Bornu, 2019).

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 (Dyner, 2000). However, in certain scenarios, some of these approaches have not effectively solved the complexities presented. The optimisation 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 (Zeng et al, 20011, DeCarolis et al, 2017). The Econometric modelling approach specifies what statistical relationship exists between the model variables (quantities and prices) and model parameters (Granado et al., 2018). 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 (Neshat, Amin-Naseri and Danesh, 2014). 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 analysing fully the environmental issues caused by oil and gas operations. Thus, the study adopts the application of the Systems Thinking/System dynamics (ST/SD) (Olaniyi, 2008) to analyse environmental sustainability issues in the NDR. 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 Niger Delta region. Figure 1.2 (causal loop diagram) captures vividly the myriad environmental sustainability issues in the NDR.

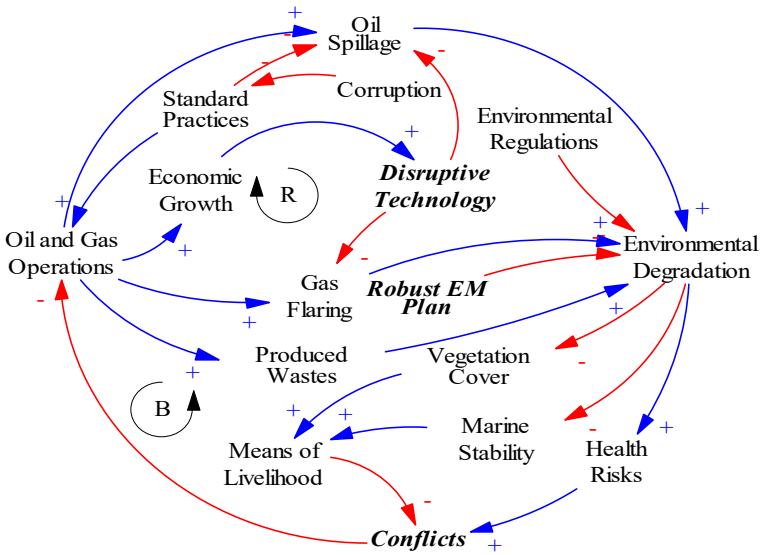


Figure 1.2 NDR Environmental Causation Sustainability Drawn using Vensim PLE (Source: Author's)

## 1.2 Aim

The study aims to apply the Systems Thinking System Dynamics tool to analyse oil and gas operations environmental sustainability issues in the NDR in Nigeria.

## 2. LITERATURE REVIEW

### 2.1 Stakeholder Theory

Freeman and Reed (1983) state that stakeholders are the divergent groups that must support organisations for them to succeed. The authors argue that there should be a stakeholder approach to issues relating to corporate governance for effective director behaviour.

However, Bryson et.al. (2002) expand the scope to include groups or individuals who can affect an organisation as well as those who are affected by the operations of the organisation. The authors argue strongly that for any organisation to achieve its corporate goals, it must attend to the concerns of the stakeholders. Dyner, Echetebu and Onyeri (2015), in a critical examination of the importance of stakeholders' engagement in the oil and gas industry in Nigeria, categorise the stakeholders in the NDR as the International Oil Companies (IOCs), organised labour, host communities, regional interests and government. The authors further state that due to the marginalisation of the stakes of the host communities, there has been constant protests, agitations and unrest in the NDR.

The authors define stakeholders as a group, individual or organisation that are potentially affected by the operations of a business or whose interests are affected by the business. They emphasise that the host communities are most affected by the oil and gas operations due to the incessant environmental degradation and social alienation they are constantly subjected to. The authors further highlight that for a meaningful sustainable development in the NDR, given that the needs of the host communities are being neglected, there is need for a stakeholder's engagement that consider the interests of all the affected parties.

Adewunmi and Olatunbosun (2015), contend that over the years attempts to solve the developmental challenges associated with oil and gas exploration in the NDR have not yielded the desired results. According to them, this has been the perception of the local stakeholders that they have been excluded from the decision-making process on issues concerning their well-being, sustenance and existence. The authors further emphasise that over the years, the Nigerian government has failed to foster a broad-based participation and stakeholder engagement in the Niger Delta region.

The authors argue strongly that the problem of a broad-based stakeholder's engagement in the NDR could be addressed through the ratification of the International Labour Organisation (ILO) Convention 169 by the Nigerian Government. They further contend that the ILO Convention 169 is a viable tool in enhancing participatory rights in the NDR due to the alteration in the Nigerian constitution. The authors stress that sustainable objectives in the NDR can only be achieved through a process of constructive consultation and inclusive participation of the stakeholders. According to them, this process is instrumental in resolving conflicts resulting from the increased exploitation of natural resources in the NDR.

### 2.2 Environmental Sustainability Issues in the Niger Delta Region

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. Albert, Amaratunga and Haigh (2018) state that despite Nigeria realising 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 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 (2017), analysing 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. This, therefore, calls for urgent attention and implementation of an effective environmentally sustainable framework which is the bane of this research.

Giwa et al, (2019), 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 region 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 sulphide are associated with FG which cause air, water and soil pollution. This has an irreversible negative impact on vegetation, ecosystem, public health and environment. The study has succeeded in highlighting the magnitude of gas flaring in the NDR as well as demonstrating its devastating impact on the environment and public health. However, it fails to recommend a sustainable approach that would reduce the negative environmental impacts whilst converting the flared gas to generate energy.

Edwin and Ugbomeh (2017) analysing 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 sulphide, 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. The study has succeeded in highlighting the negative impacts of gas flaring generally, however, it does not proffer any solution to the problem.

Yakubu (2017), 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. He proposes a robust environmental management plan/system and compliance with environmental laws to remedy the situation. These proposals are not sufficient to solve the endemic environmental issues as they do not tackle oil and gas operational processes which are the main causative factors of environmental pollution in the NDR.
In agreement,

Temilola et al (2020), analysing data collected on the effect of PW, note that it contains huge amounts of crude oil pollutants and by-products such as metal derivatives, polycyclic aromatic hydrocarbons (PAHs), naphthenic acids, phenols and other chemicals. These substances are toxic to the ecosystem; thereby destroying the mangroves and aquatic organisms. The study has succeeded in highlighting to a high degree, the toxicity of PW on the eco-system, however, it fails to address what mechanism/framework can be put in place to reduce the toxicity of PW.

## 3. METHODOLOGY

This study applies the Systems Thinking System Dynamics (ST/SD) methodological tool (Olaniyi, 2014) to analyse Oil and Gas Operations Environmental Sustainability Issues in the Niger Delta Region of Nigeria. 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.

### 3.1 The Research Design

This is the plan that this research employs to execute the aim of the study. It outlines the research philosophy, approach, strategy, data collection methods, research limitations and ethical considerations (sileyew, 2019). To carry out this objective, the research onion model has been adopted to ensure cohesion of all the elements of the research for effective delivery (Saunders, Lewis and Thornhill, 2018). Figure 4.1 outlines the elements of the research onion. To fully understand the issues in the Niger Delta, this research employs the Systems Thinking (Olaniyi, 2014) tool to uncover the operational practices associated with the production of oil and gas. It is suitable for a complex situation such as the Niger Delta area, the elements of feedback and delays would further enhance the development of a sustainable framework for the region.

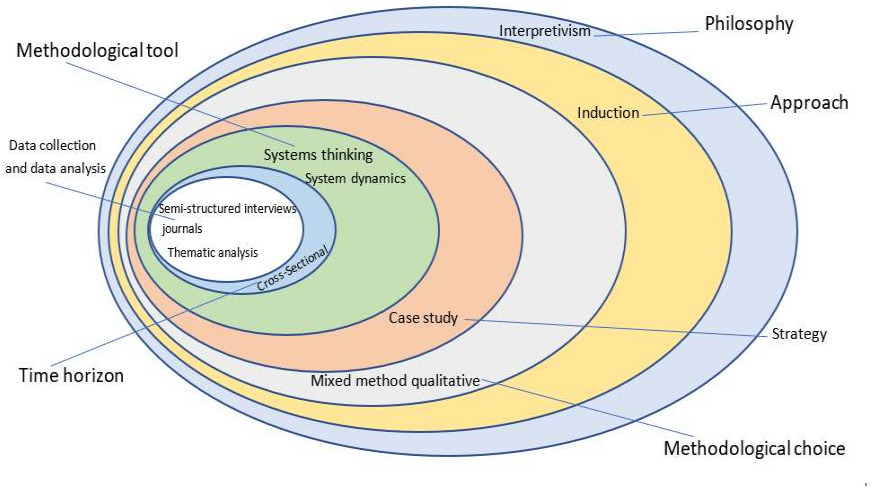


Figure 4.1 The Research Onion Model Adapted (Source: Saunders, Lewis and Thornton, 2018)

## 4. INITIAL RESULTS, DISCUSSION AND INITIAL FINDINGS

### 4.1 The Effects of Oil Spillages on Farming

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 into wastelands (Akpokodje and Salau, 2015). The 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; a major factor. Table 6.1 below shows that oil spillage is a major factor in the losses of cassava production in the host communities.

Table 4.1 Major Causes of Losses of Cassava Production

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

Source: Adapted from Ahmadu and Egbodion (2013)

As could be seen in the data presented in Table 6.1 above, 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.

The causal loop diagram below (Figure 5.1) demonstrates succinctly, the effect of oil spillage on the means of livelihood of the people.

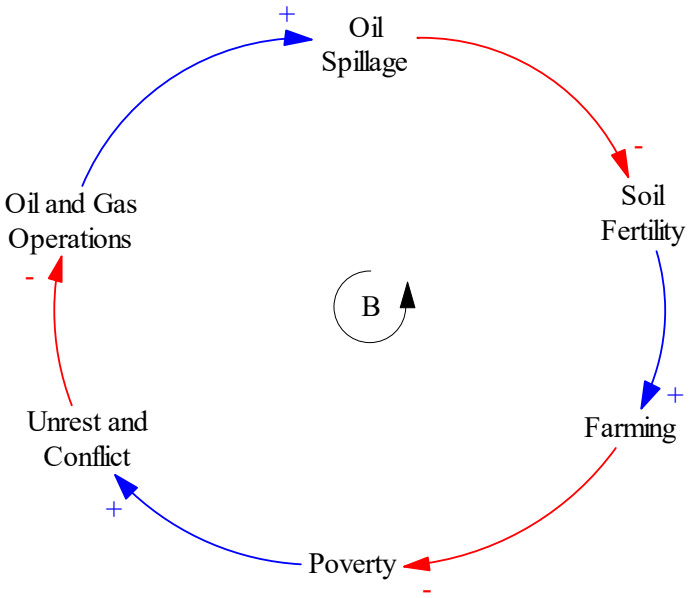


**Figure 5.1 shows that for oil and gas production which is the mainstay of the Nigerian economy to continue unhindered, the issue of oil spillage must be addressed.**

### 5.2 Environmental Degradation in the Nigeria Niger Delta

The NDR has been subjected to environmental degradation due to oil and gas activities; resulting from oil spillages, gas flares, unwholesome disposal of wastes, erosion, etc. This has led to the pollution of farmlands, fish ponds; consequently, causing the destruction of properties, human lives, including aquatic and biodiversity (Ugboma, 2015). Despite the huge contribution of the NDR to the economic prosperity of Nigeria through oil revenues, the oil host communities, continue to suffer untold hardship. Environmental degradation as depicted in Figure 5.8, in the oil-rich region poses a serious threat to human survival; unleashing excruciating pains in terms of poverty and deprivation (Oshwofasa, Anuata and Aiyedogbon 2012; Ugboma, 2015).

Over the years, this has resulted in the people engaging in different forms of agitation and conflicts as the only avenue of seeking the attention of the government for even development and socio-economic emancipation of the region. According to the World Bank report on the region the state of environmental degradation of the region, all indices of development seriously fell short of acceptable standards (Ugboma, 2015). Gas flaring is one of the major causes of environmental degradation in the NDR, with about 36.79 bcm of natural gas flared annually (Oka, 2017) resulting in health implications for the people living in the region.

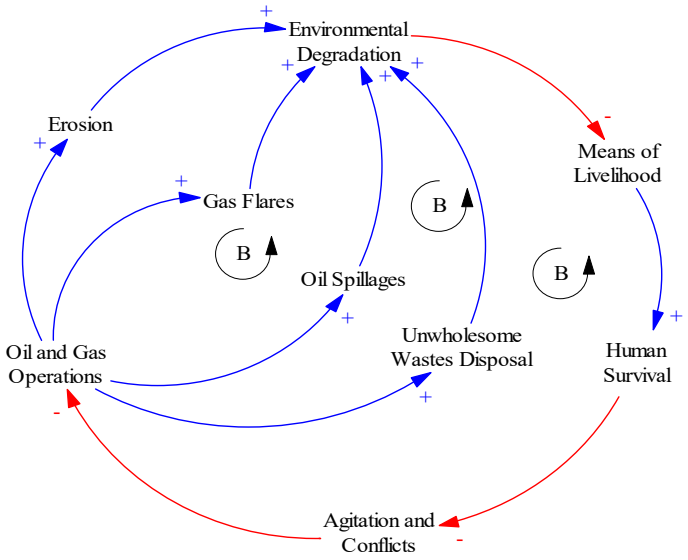


**Figure 5.2 NDR Oil Environmental Degradation Causation Sustainability Drawn using Vensim PLE (Source: Author's)**

### 5.3 Gas Flaring and Public Health in the Nigeria Niger Delta

Gas flaring in the Niger Delta region has; negatively impacted bio-diversity, contributed to global climate change and led to serious health challenges (Edwin and Ugbomeh, 2017). 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 (2020) on gas flaring by top 30 countries shows that as of 2019, Nigeria ranks 7th. 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 Greenhouse gasses. Secondary data analysed, reveals that residents living close to gas flaring stations are at a higher risk of diseases relating to air pollution such as asthma, cough, chest pain, breathing difficulty, dizziness and eye irritation (Nwosisi et al., 2021) The Table 5.8 below is a comparative analysis of data from 6 Public Health Centres of reasons why people who live close to gas flaring stations visit hospitals.

**Table 5.2 Disease Distribution in Sampled Primary Health Care Centres (2013-2016)**

| Diseases | PHC1 | PHC2 | PHC3 | PHC4 | PHC5 | PHC6 | Total |
|---|---|---|---|---|---|---|---|
| | Freq | Freq | Freq | Freq | Freq | Freq | Freq |
| Respiratory problems/Dizziness | 1338 | 573 | 3315 | 1072 | 3914 | 2535 | 12747 |
| Measles | 9 | 0 | 20 | 528 | 42 | 30 | 629 |
| Weight Loss | 6 | 0 | 350 | 654 | 177 | 296 | 1483 |
| Boil | 37 | 3 | 89 | 254 | 105 | 64 | 552 |
| Pneumonia | 516 | 26 | 62 | 857 | 27 | 2 | 1490 |

Source: Adapted from Nwosis et.al., 2021

From Table 5.2, secondary data analysed from 6 Primary Health Care Centres close to gas flaring stations reveal that between 2013 and 2016, residents suffer more from respiratory problems and dizziness, resulting from gas flaring. This has been captured succinctly in Figure 5.10 below.

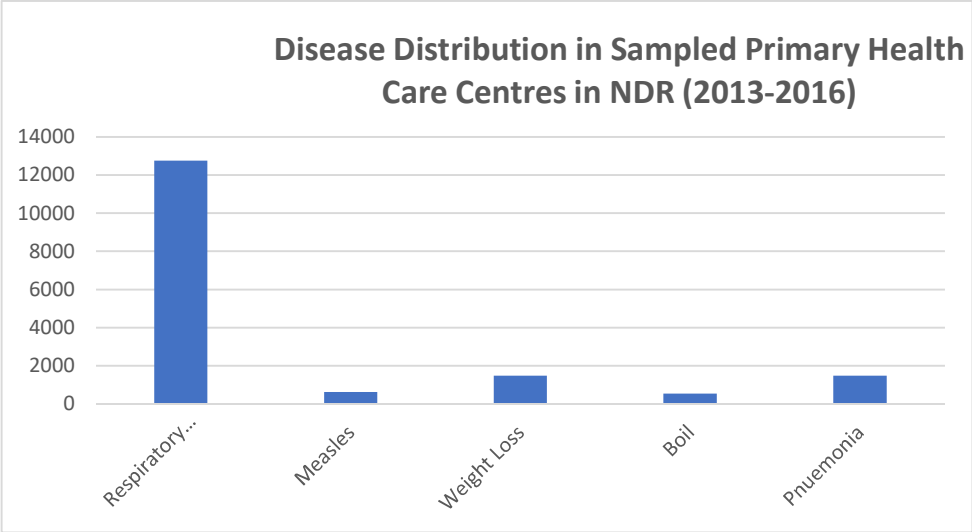


Figure 5.3 Disease Distribution in Sampled PHC in NDR – 2013-2016
(Source: Adapted from Nwosis et.al., 2021)

As demonstrated in Figure 5.3, over 1200 cases of respiratory and dizziness problems were reported by the residents in three years, this shows the magnitude of respiratory issues caused by gas flaring. This has resulted to agitation and unrest in the host communities.

## 6. CONCLUDING REMARKS AND FUTURE WORK

This section brings to a conclusive end the academic process involved in the application of Systems Thinking System Dynamics tool to analyse oil and gas operations environmental sustainability issues in the Niger Delta Region of Nigeria. The Niger Delta region has been bedevilled with environmental degradation since the discovery of oil and gas in 1956(Effiong, 2010). A forensic analysis of the available Literature on the subject domain revealed the magnitude of environmental degradation in the NDR. High levels of oil spillages have destroyed farming and fishing businesses (main sources of income) of the host communities as well as impacting negatively on public health (Oladipupo et.al., 2016).

Given the complexities of the NDR, Systems Thinking System Dynamics (ST/D) methodological tool (Olaniyi, 2014) has been adopted to analyse the environmental sustainability issues arising from oil and gas operations in the NDR. environmental sustainability issues in the Niger Delta Region of Nigeria. There is a need to strike a fine balance between two extreme ends of the environmental impacts of oil and gas operations and the economic benefits to the producing state. The incorporation of sustainable approaches in oil and gas operations is already being implemented in some of the producing countries of the Global North.

In Norway Netherlands and Spain, the carbon capture and storage (CCS) technology has been deployed on some projects. According to the Intergovernmental Panel on Climate Change report (2005), the CCS technology can capture up to 85%-95% of CO2 released into the atmosphere. Despite the demonstration of its effectiveness, it is yet to be deployed globally to harness flared gas and convert it to other use.

Future work includes developing an environmental sustainability framework to manage oil and gas operations in the NDR in Nigeria. A wider critical review and analysis of Literature on the subject domain needs to be carried out. This would cover extensively pertinent issues bordering on the implementation of an environmental sustainability framework. As proposed in the methodology section, semi-structured interviews with key industry stakeholders would be carried out and analysed. The Systems Thinking System Dynamics (ST/SD) methodological tool would be used fully to capture aspects of the non-linearity, feedback and delay that are inherent in the NDR scenario. Finally, other areas key to the development and implementation of the proposed future work on environmental sustainability framework would be critically explored. This includes local and international environmental regulations, an environmental management plan and financial capacity.

## 7. CONTRIBUTIONS TO KNOWLEDGE

In light of the literature review and study evidence, the following recommendations are suggested:

- 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.
- 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.

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