



Research article

Examining the causes and impacts of pipeline disasters in Nigeria

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Abstract: The effect of pipeline vandalism among other pipeline disasters has been drastic on the Nigerian economy. The research aims to examine the level of awareness of stakeholders on the immediate and remote causes of pipeline disasters in Nigeria. This involved comprehensive review of literature along with semi-structured and open-ended interviews (as a pilot study) to enrich and strengthen the literature in Nigerian context and subsequently follow-up with semi-structured questionnaire survey; analyzed through content analysis using both descriptive and inferential statistics. In the methodology, three levels were adopted: confirmatory factor analysis (CFA), measurement model and structural model in the carrying out of structural equation modelling (SEM) analysis. The CFA analyzes the relationship between the dominant's variables and their related indicators. Based on the analysis carried out, activities of vandals has the highest influence on pipeline disasters. Human impacts resulting from pipeline disasters are very significant in Nigeria. Also, ecological impacts resulting from pipeline disasters have been extremely significant in Nigeria. There is high level of awareness of pipeline disasters among the different stakeholders interviewed.

Keywords: oil spill; oil theft; vandalism; environmental impact mitigation; confirmatory factor analysis; structural equation modeling

1. Introduction

1.1. Pipeline disasters

The frequency of tragic pipeline incidents in Nigeria has drawn attention from around the world [1]. This negative impact on people and the environment, which includes ongoing human and animal deaths, pollution of the water and air, soil contamination, eradication of the ecosystem (flora

and fauna), destruction of property and infrastructure, and loss of crude oil and refined products, is what has garnered this attention on a global scale. Using the analogy of a human vein to describe the important role that pipelines play, [2] stated that “*Pipelines serve like veins helping to provide life-necessities like natural gas or water and to remove life wastes like sewage*”. Additionally, they are thought of as the most favorable way to transport large amounts of gas or fluid. Nigeria's vast oil output and oil potential have resulted in oil vandalism, militancy, inadvertent spills related to oil transportation, ecological harm, and more [3]. Under these circumstances, there is a greater chance that a tragedy will occur if appropriate steps are not taken to reduce the risks associated with the oil crisis. Significant problems could result from this, especially in the areas where oil is produced. As the significance of petroleum resources as a substantial source of economic advantages became increasingly obvious, the resource regions were more susceptible to a series of military attacks and regional pressure [4,5]. Oil-related issues are particularly common in Nigeria's Niger Delta or South-South region, which is where the majority of the country's main reserves are located [6].

The extraction, processing, and transportation of petroleum have resulted in ecosystem disturbance, environmental harm, and mortality in several developing countries [7–9]. Oil-related problems, such as oil spills, crude oil theft, illegal refining of crude oil, accidents involving oil trucks, pipeline vandalism, and explosions, were exacerbated by the government's inability to control the practices surrounding petroleum management [10,11]. In practically every part of the world, people view these problems as the principal ones with relation to oil extraction because they endanger both human life and the environment. A disaster is an unexpected occurrence or natural catastrophe that severely impairs the functioning of a community or civilization and, as a result, affects both human and economic activities. It is a phenomenon that results in considerable loss and tragedy, and when it happens, it can devastate people's lives, their possessions, and their economic and cultural well-being. In addition to disastrous natural events like earthquakes, wildfires, floods, windstorms, and tsunamis, catastrophes can also be brought on by human activity, such as pipeline explosions or pipeline vandalism.

1.2. Geographical distribution of pipelines in Nigeria

Nigeria dependent ratio many years back is on agriculture and of course most of the produce from farms are transported by roads or rails. However, when the discovery of the natural resources; crude oil, there was more reason to make provision for the transportation of crude oils and this brought about the pipeline transport system. Pipeline transport system is the transportation of gases, liquids or semi liquids produce such as crude oil through a tunnel or tube from one part of the country to the other [12]. Pipeline is a highly specialized mode of transport that also cut across all essentials of a transport system in level of the physical structure, the direction and of course the point of delivery [13]. The network of this pipeline transport system has cut across all parts of the country and territory such that it can be used to transport crude oil from the point of refinery to the point of use either as raw material or to be exported to other countries [12].

Pipelines because of the precious natural resources it transports, is buried about 1–1.5 metres below the ground so as to avoid contact with easy damage or some of the other purposes the land might be meant for. As of the fact that the pipeline system is properly covered and managed underground, there comes human pest reasons in order to vandalize the pipelines for the proliferating of the natural resources. Nigerian National Petroleum Corporation's (NNPC) pipelines network

system made provision for networks of pipelines that are connected to 21 white product depot and tank across the nation [14].

Most of the pipelines transport system arise as a result of a project name; such as Trans-Nigeria Pipeline, Offshore Gas Gathering System (OGGS), Escravos-Lagos Pipeline System (ELP) and many more. By the day many pipelines are been produced to ensure steady supply of crude oil to all desired destination of the country [15]. The total length of pipelines in Nigeria is approximately 5001 kilometres. This includes 666 kilometres of crude oil pipelines and 4,315 kilometres of pipelines carrying multiple products. These pipelines traverse the country, connecting the 22 petroleum storage facilities, the four petroleum refining plants (in Port Harcourt I and II, Kaduna, and Warri), the off-shore terminals (in Bonny and Escravos), and the jetties (in Atlas Cove, Calabar, Okirika, and Warri) [16]. This network of oil pipelines, stretching over a total of 719 kilometres, is used to transport crude petroleum to refineries at Port-Harcourt (I and II), Warri, and Kaduna. Refined products are transported from refineries/import receiving jetties to oil storage depots across the country via multi-product pipelines. The pictorial representation of pipeline network across Nigeria can be found in Figure 1.

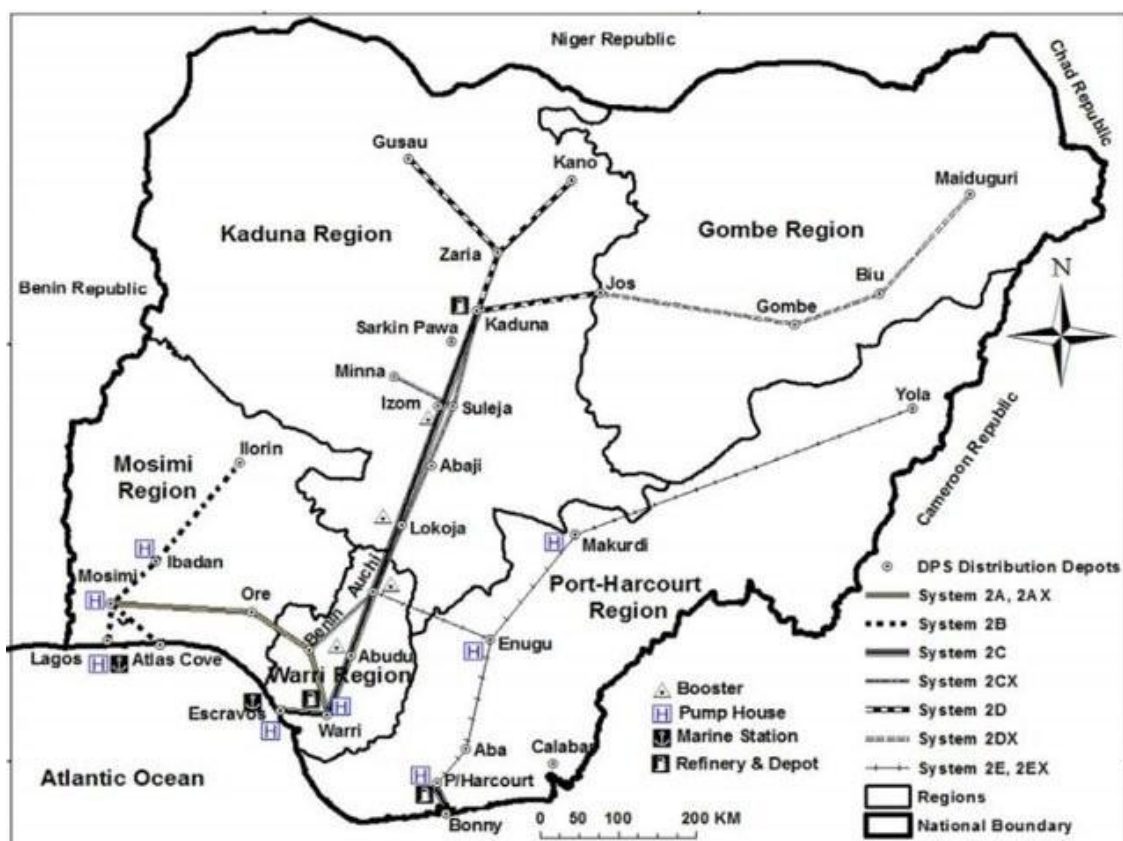


Figure 1. The Network of Pipelines in Nigeria [17].

1.3. Objectives

The aim of this research is to examine the causes and impacts of oil pipeline disasters in Nigeria. This aim was achieved through the following objectives;

- i. Examine cases of pipeline disasters in Nigeria between years 2000 to 2019 with a view to

- identifying the immediate and remote causes.
- ii. Assess the human and ecological impacts of such occurrences
 - iii. Examine the level of awareness about pipeline disaster amongst different stakeholders

1.4. Research implications and contributions

Given the challenges in pipeline disaster faced by Nigeria, especially in the oil producing regions, the results of this research have implications for policy, practice, baseline studies and planning scholarship. First, this research adds occurrence of pipeline disaster. Second, the findings from this research will provide us with on field report on the cases of pipeline disasters in Nigeria from the year 2000 to 2019 and will provide tentative information on human and ecological impacts of such occurrence. The findings provide policy makers and planners with information about the occurrence, ecological and human impacts of pipeline disaster in Nigeria and sustainable approaches to mitigate it.

2. Literature review

2.1. Development of pipelines

The existence of pipeline has been way back from many years ago from the time of inception. Although, not as standard and widely used as it is now but still having a number of purposes that cannot be underestimated. Research has it that this pipeline system has been in use since when the Egyptians use copper pipes to transport water in 3000 BC [18]. The pipeline industry began to grow another productive phase of effort especially in the 19th century. It gave a way turn up of interest massively by all developing and developed countries as the only means to transport chemical elements including hydrogen or other viscous and important liquids as crude oil. By the 20th century, pipeline transport system was all over and the level of interest and research audience it has gained became so spontaneous to the economic value of all countries having any relationship with the mineral resources and other worthwhile chemical use. By 2007, the total length of the transmission pipelines has grown tremendously to about 3,500,000 km. This high-pressure pipeline systems are majorly used for the transport of natural gas while the others are used for transporting crude oil and other petroleum products [19]. Under different subjections, pipelines can be classified on the basis of materials it's made from or the technicality in its construction. However, the best form of classifying pipelines is on the basis of the function or purpose it is serving [20].

2.2. Pipeline failures

Pipeline failure does not necessarily imply that the quality of the material used is inferior or perhaps, the experts or company have not done a good job. There are many other factors that could have resulted into pipeline failure such as environmental abuse, coating disbandment, external damage, soil movements and third-party damage. Pipeline failures literally occurs as a result of environmental failure, materials properties and stress. For every time there's a pipeline failure and there's an emission of product from the pipeline, there will always be loss in property, environmental damage such as injuries or even fatalities. This same liquid could also pollute the water bodies and

thereby increasing the toxicity of such water for the aquatic animals or wild life and other uses the water body maybe subjected to. This same scenario can lead to economic loss as the natural oil and gas becomes depleted as a result of failure of the pipelines [21].

According to a statistical research from the United States on the failure results of pipeline, it has shown that the economic and human loss due to significant pipeline incidents over a 20-year period (1996–2015) are \$7 billion; 324 fatalities along with 1,333 injuries, respectively [21]. The Nigerian petroleum industry faces numerous challenges with the current system of pipeline in use. Parts of these challenges are cases of vandalism and militancy and as a result the Niger Delta region suffers the most. Although the activities of militancy have been immensely suppressed since the amnesty program that was launched in 2009 [22] in recent years, the activities of vandalism are seemingly resurfacing in these regions. 16,083 pipeline breaks and leaks were reported in the last 10 years and added that 398 of the reports were as a result of ruptures. The remnants cases recorded are as a result of the activities of vandals which significantly affected the Nigerian economy and environment and eventually the loss of lives and property [3].

The failure types that may likely occur from the above stated occurrences are classified under the major headings shown in Figure 2.

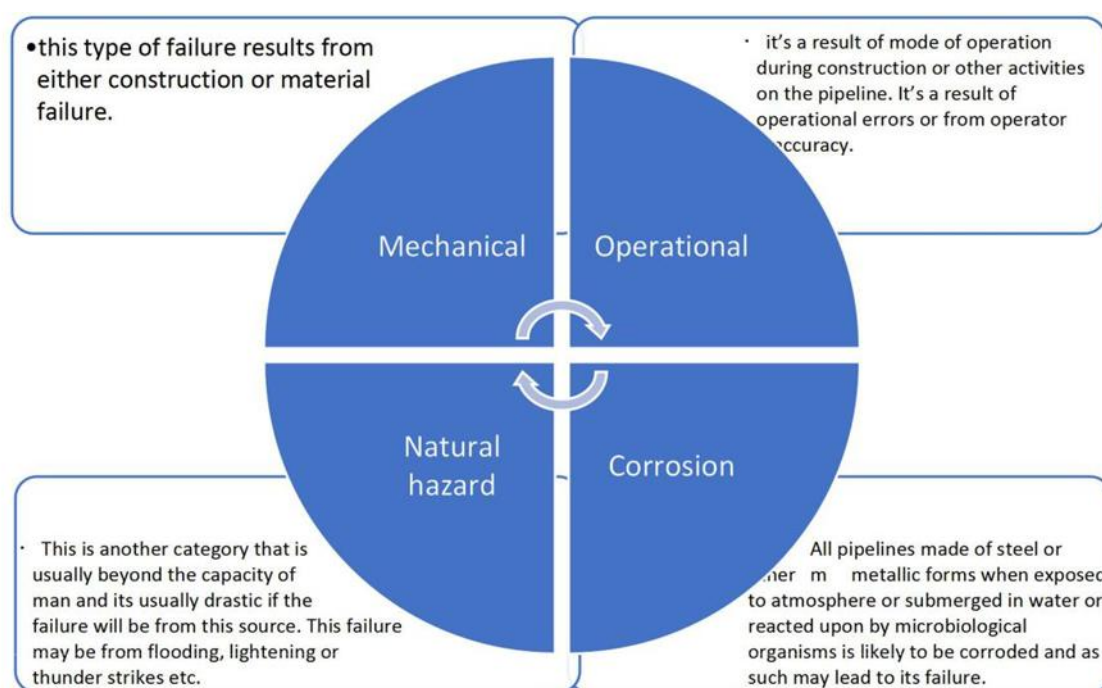


Figure 2. Classification of pipeline failure.

In addition to the four factors mentioned in Figure 2, we can also include *Third party*: This action results from an intentional act of a person or group of people. This set are always targeting a wide or large quantity of loss as it is usually well planned or arranged. In total, the percentage of each of the above failures are Mechanical – 25%, Operational – 7%, Corrosion – 30%, Natural hazard – 4%, Third party – 33% and Others – 1%.

2.3. Causes of pipeline disasters in Nigeria

Crude oil has offered so much to the economy of Nigeria and many other African countries such that crude oil is often referred to as black gold and the boom of wealth. As much as this importance is accrued to crude oil, the transport system of crude oil called Pipeline system has recorded lots of accidents and disasters. Pipeline accidents have caused large loses to Nigeria in terms of economic, ecological and human lives. A single incident can have devastating consequences for the environment, individual communities, and local economies. A report by [1] stated that the first incident of pipeline rupture in Nigeria occurred in Warri Delta State between the period of July 11 and 17 July, 2000. This incident occurred in a village Adeje and it claimed a lot of lives more than the incident that occurred in the community of Jesse people in Delta state too which claimed over 1,000 lives [23]. Statistics have shown that Nigeria is losing well over 300,000 barrels per day (bpd) as a result of crude oil pipeline vandalism, which runs into billions of dollars in losses [24].

The rupture of a pipeline at every level is dangerous to human and environment. [25] also reported another incident of explosion that occurred in July 2000 near the villages of *Oviri* and *Adeje* resulting to the death of about 250 persons. It's amusing to state that the majority of these cases were results of unscrupulous persons attempting to part away with petroleum products. Also, vandals intending to hold the government to ransom cause these ruptures. Pipeline ruptures lead to the release of toxic materials in to soil of affected environment and as well affect the quality of drinking water.

The region of Niger Delta appears to be the region in Nigeria that has witnessed the highest number of oil disaster and production activities [26]. The vulnerability of the oil pipeline to incessant attacks may be as a result of the networking styles of pipeline. The cases of pipeline disaster have been reported to mostly occur as result of deliberate damages, poor maintenance and overuse of pipes subjecting it to corrosion, inadequate surveillance giving room for vandals to perpetrate evil. Takako (1996) reported that 50 percent of oil spillage cases in Nigeria are caused by corrosion, 28 percent due to saboteurs and 21 percent due to production processes. Recently, SPDC, 2019 argued that oil spill due to sabotage is now about 50 percent and corrosion and operational faults has drastically reduced. Pipeline sabotage is considered next to pipelines corrosion as a major cause of petrochemical spill in the country. Some individuals may form a militant group especially in the oil producing Niger Delta and conduct premeditated destruction of oil pipeline in a bid to usurp oil from the producing companies [27].

According to [1], pipeline explosion in the last 20 years had led to the death of numbers of looters, militants and passers-by. One of the most dangerous pipeline explosions was the one that happened in Ilado, Lagos Island on May 12, 2006. This incident led to the incineration of more than 200 people as a result of the pipeline fire. Apart from high death rate and loss of property, soil, land, water and air deteriorations has also been witnessed in these regions. The activities of fishermen and other recreational activities are also affected after by pipeline disasters. It was estimated that Nigeria incurs losses amounting to N29.4-billion-Naira equivalent to about \$10.4 million per day as a result of pipeline sabotage. In other reports, an average of 200,000 bb/d of crude oil or some 10 percent of its total output to theft [1,26]. In a country like Nigeria where Democratic government is run and understanding makes it clear that everyone has right to the economic resources and all other facilities that the country has [28]. Whenever such resources are not circulated, the people that is faced with backwardness, denied and deprived of the right to enjoy social benefits sees need to tamper with the private and public resources which may result in emotional stress [29]. The motivation in the denied

group of people's minds will be on the high side taking into consideration that they lack good health services, educational facilities, housing, leisure and employment opportunities. The marginalized group feels cheated and marginalization has a significant relationship with vandalization and breaking down of society morals and norms. About 28% of Nigeria population is unemployed and about 40% is underemployed which makes a total of 68% that could decide to go in for any employment opportunity even if it's against social norms (National Bureau statistics, 2018). Furthermore, [30] found out that there is a positive relationship between unemployment and crime, especially among people with lower educational levels and its magnitude on the economy is significant. This rail on the same line that it becomes possible for unemployed youths to result in vandalism of pipelines which may also cause oil pipeline disasters.

Another cause to be considered is the institutional factor. Corruption anywhere is a threat to corruption everywhere. A number of African countries shows positive relationship between poor governance and vandalism. This is also why many African laws are weak and not able to stand against the vandalizers who were facing high inflation rate poor accountability on the tax they have consumed. General research interest can be affirmed that vandalism than all other accidents accounts for 70% of the accidents and disasters of pipeline in Nigeria.

2.4. Oil pipeline vandalization: manifestation and consequence

Historical Factors leading to Vandalization: We have earlier stated that the history of vandalisation is traced to the general perception of being frustrated as the people are deprived from benefiting the huge revenue sourced from the region since 1956. Nigeria is, for example, the world's seventh largest exporter of petroleum and fifth largest supplier of crude oil to United States because of the Niger Delta, and yet does not benefit from it. Therefore, the people of this region, looks at oil as more of a curse than blessing, considering the level of underdevelopment, poverty, environmental degradation, and poor infrastructure in the region. Onuoha explains how incidences of pipeline vandalization with concomitant cascading explosions have posed threats to life and property in the region and the country. Therefore, the three main factors that account for pipeline vandalism in Nigeria are; Oil production operations (21%); Sabotage (29%); and Corrosion (50%).

The analysis points to corrosion as the major factors responsible for pipeline vandalization. This is followed by vandalization (sabotage) which is induced by poverty and unemployment. This explains how the economic motive has made the exercise of breaking pipelines difficult to wane, and the number of actors continues to increase.

2.4.1. Manifestation of vandalization

In commenting on the "dangers of oil and gas pipelines in the Niger Delta", the coalition of the Niger Delta Organization in Diaspora (CNDOD)" wrote, "beginnings from 1976, under the government of General Olusegun Obasanjo, pipelines were laid in the Niger Delta to take oil to Kaduna in extreme Northern Nigeria. Since then, the Niger Delta is trapped into pipelines which *criss-cross* the entire region. Many of the pipes have aged and are without proper maintenance. Moreover, they have been vandalized by sophisticated thieves, secured by privileged millionaire-thieves."

In addition to the issues raised by Coalition Niger Delta Organization Diaspora (CNDOD), Onuoha, Freedom has identified five key factors responsible for the growing incidence of pipeline vandalization in the country [16]. They are listed below:

- i. The prevalence of poverty and unemployment.
- ii. The emergence of barons or godfathers who induce the vandalization;
- iii. The defective security apparatus
- iv. The official negligence of MNOCs and federal government; and
- v. The weak framework

He went further to argue that, while the five factors have created so much havoc to communities, the oil pipelines fire disasters rarely consume the vandals themselves. Instead, it is the poor who either come to collect the leaking fuel after a pipeline has been broken. This category of people is the hardest hit by such disasters, poverty and vulnerability to pipeline fire in Nigeria are closely linked since the poorest live in the highest area, i.e., where the pipelines traverse. They also constitute the highest number of displaced people in the region. Incidentally, this underlying socio-economic reality is often not considered in official perceptions of pipeline vandalization explosions.

The reference [31] addressed the manifestation from the perspective of its “impact on public health and negation to the attainment of the millennium development goal” by studying Ishiagu community in Nigeria (Anambra state). They argue that oil spill can occur through mechanical failure, operation error, as well as, third party activity and sabotage. They observed that “oil pollution is one problem for which no effective and final solution has been found anywhere, not only in Nigeria, but in the world in spite of efforts to control it. Thinks that there are solutions, and measures to control pipeline vandalization in the country. As puts it, “we’ll stop bunkering, vandalism in Niger Delta creek the “scourge has eaten deep into the fabric of the society”. The group plan to mobilize local communities along the coastal zone and security outfits to fight the problem, insisting that the “nation’s battered economy must be redeemed” while “stopping pipeline vandalization” is highly desirable, to what extent and his group would succeed is difficult to say. The consequences or effects of oil pipelines vandalization cannot be exhausted, but we have discussed few of them in this section. Oil pipelines vandalism has, indeed fueled criminal interests and conflict. The economic interest now overrides that of social which used to an opposition against the oppressive actors of the MNOCs and federal government. The interplay of economic and social forces has resulted in displacement of large population after the disaster that accompanies the vandalization.

2.4.2. The consequences

In our recent study on oil spills, we stated that it occurs in the Niger Delta with such a frequency that between 1976 and 1990, the industry had 2,676 cases. This rose to 7,563 cases in 2004; and 9,500 cases in 2008. The loss from spills in 2006, alone was 4,992,764 barrels. The said study further revealed that MNOCs, especially SPDC have not demonstrated significant commitment to mitigate the effects of the oil spills. One of the critics of SPDC on this matter was Bopp Van Dessel, a Dutch. Van Dessel resigned in protest as the Head of the Environment study unit in SPDC in 1999. Prior to the resignation, he accused SPDC of using different standards of operations in Nigeria as compared to the practice in other parts in the world. Where, the waste is burnt, but in Nigeria, the cleaning of crude oils is done by bucket and spade. In this process, the waste is deposited in large trench, and the sketch of land is lost forever, Human Right watch, 1999. In consequence, whenever it rains, the

underground water sluices force the crude oil to the surface and poisons the earth, flora and fauna, and rivers in the region.

The Nigerian National Petroleum Corporation (NNPC), a Federal Government owned oil empire, reported in 2006 that the 20 MNOCs operating in the country spilled 2,500 cubic meters of oil in 400 separate incidences annually. It is, however, safe to argue that due to under reporting, the actual figure would be much higher than this conservative estimate they presented. As it we knew, after five years (i.e., 2010), the same NNPC provided graphic details of the activities of pipelines vandalization and contends that 98.5% of the ugly incidences are due to sabotage by Niger Delta militants. This shows the dearth of record keeping in this country.

The Department of Petroleum Resources (DPR) reported a different type of consequences in 2004. It stated that MNOCs operating in Niger Delta generated 90,000mtons of hazardous waste, an increase of 7.7%, from that of 2004. In spite of this size, the SPDC's "people and Environment Annual Report" of 2005, went further to state the increase does not still include the sewage at "Edigba Sewage Treatment plant". SPDC also admitted that it is not complying fully in some areas of the DPR's regulations. Already, the issue of compliance with environmental standard is now a thorny matter between DPR, the Oil Producers Trade Section of Manufacturers Association of Nigeria (MAN) and the Federal Ministry of Petroleum.

3. Materials and methods

3.1. Study Area

The study area is Nigeria, and it stretches through 923,769 km² a range of which 13,000 km² is covered by water across 36 states from north to south. With a population of 187 million in 2017, the nation has substantial resources including crude oil. In Nigeria, states which are the largest oil-producing states and make up the 9 Federating States in the Niger Delta Region of Nigeria are, Cross River, Abia, Akwa Ibom, Ondo, Rivers, Delta, Bayelsa, Imo and Edo States.

3.2. Data source

This study used primary data. The primary data from a collection of data with well-structured questionnaires and employed the use of Structural Equation Model (SEM) for analyzing the proposed objectives. The well-structured questionnaires were shared among the respondents and they were administered to them in the study area with adequate explanation and guide for putting them to the right response from their perspective. The respondents were given enough time to see to the different sets of questions relating to causes of pipeline disasters and its reaction on the environmental issues, their awareness about the effects, and their consent level about the significance of environment using the Likert-scale options.

3.3. Research methodology

In the study three levels were adopted: CFA, measurement model and structural model in the carrying out of SEM analysis. The first two are the preparation of data for SEM companies while the third is the complete SEM analysis. The CFA analyzes the relationship between the dominant's

variables and their related indicators. This was used in analysis of the objectives i and ii for the questions are undoubtedly the factors of causes, as well as the ecological and human impacts. A logit regression model is used to examine the relationship between the level of awareness of pipeline disasters and the collaboration of the Stakeholders. Logit regression is adopted because the outcome the dependent variable is binary (i.e., it is either high or low).

3.4. Ethics approval of research

Prior to the commencement of data collection, approval was sought from the research board arm of the Robert Gordon University (RGU) so as to ensure strict compliance with the necessary legal and ethical requirements as stipulated by the University. All ethical procedures and guidelines were followed so as to protect the research participants' anonymity and confidentiality, maintain the study integrity and data security.

4. Results

The main purpose of this section is to present and outline detailed analysis of the findings and interpretation of the findings of the empirical research conducted. For the survey, a monolingual (English) email and social media was sent to one thousand and fifty (1050) targeted respondents which had been identified as constituting the valid sample, inviting the respondents to participate in the study. The invitation contained the URL link to the online survey instrument hosted on Google survey form. Out of over one thousand and fifty (1050) targeted respondents, 962 (91.61%) responses were received. However, upon cleaning the data, 832 (86.5%) responses were included as valid responses for analysis, representing an 86.5% (832/962) response rate. The analysis was carried out using AMOS 24.0 (an SPSS module).

4.1. Causes of pipeline disasters in Nigeria between years 2000 to 2019 with a view to identifying the immediate and remote causes?

Table 1. Causes of pipeline disasters in Nigeria between years 2000 to 2019.

Statements	N	Minimum	Maximum	Mean	Std. Deviation	C.V
Activities of vandals	832	1	5	3.93	.797	0.203
No Community-based security team to monitor the pipeline	832	1	5	3.83	.866	0.226
Exposed pipeline due to erosion and age	832	1	5	3.83	.907	0.237
Lack of adequate maintenance of pipes, joints and valves	832	1	5	3.90	.906	0.232
Mechanical failure	832	1	5	3.79	.954	0.252
Operational error	832	1	5	3.83	.938	0.245

Research question one sought to identify causes of pipeline disasters in Nigeria between years 2000 to 2019. However, the study first sought to find out how frequent this causes influence pipeline disaster as observed by respondents.

Table 1 showed the causes of pipeline disasters in Nigeria between years 2000 to 2019. The study showed that pipeline disaster is frequently influenced by being activities of vandals (mean=3.93, CV=0.203), having no community-based security to monitor the pipelines (mean=3.83, CV=0.226), exposed pipeline due to erosion and age (mean=3.83, CV=0.237), lack of adequate maintenance of pipes, joint and valves (mean=3.90, CV=0.232), mechanical failure (mean=3.79, CV=0.252) and operational error (mean=3.83, CV=0.245). This showed that according to the respondents' observation, pipeline disasters were frequently influenced by all of the causes aforementioned, and activities of vandals has the highest influence on pipeline disaster.

4.2. Level of Human and Ecological Impacts of Pipeline Disaster in Nigeria?

Research question two sought to identify the level of human and ecological impacts of pipeline disaster in Nigeria.

Table 2. The level of human and ecological impacts of pipeline disaster in Nigeria.

Ecological Impacts	N	Minimum	Maximum	Mean	Std. Deviation	C.V
Water Contamination	832	1	5	4.20	.797	0.189
Pollution of soil by hydrocarbons	832	1	5	4.10	.903	0.220
Environmental pollution/degradation	832	1	5	3.93	.875	0.222
Loss of vegetation	832	1	5	3.97	.957	0.241
Destruction of farmlands	832	1	5	3.95	.924	0.234
Destruction of aquatic ecosystems	832	1	5	4.01	.914	0.228
Human Impacts						
Adverse health effects	832	1	5	3.87	.878	0.227
Loss of lives	832	1	5	3.83	1.028	0.268
Increase in the price of drinking water and other commodities	832	1	5	3.60	1.063	0.295
Loss of properties	832	1	5	3.75	1.091	0.291
Pollution of air for respiration	832	1	5	3.86	.968	0.251
Scarcity of food	832	1	5	3.77	1.068	0.283

Table 2 showed the level of human and ecological impacts of pipeline disasters in Nigeria. On the ecological impact, the study showed that there was a high level of agreement that pipeline disasters leads to water contamination (mean=4.20, CV=0.189), that pipeline disasters also leads to pollution of soil by hydrocarbons (mean=4.10, CV=0.220), that pipeline disasters results to environmental pollution/degradation (mean=3.93, CV=0.222), that it also contributes to loss of vegetation (with mean=3.97, CV=0.241), pipeline disasters also leads to destruction of farmlands (mean=3.95, C=0.234) as well as destruction of aquatic ecosystem (mean=4.01, CV=0.228). On the human impacts, the study showed that there was agreement from the respondents on the statements that pipeline disasters contributes to adverse health effects of inhabitants in the region (mean=3.87, CV=0.227), that pipeline disasters causes unwarranted loss of lives (mean=3.83, CV=0.268), and increase in the price of drinking water and other commodities (mean=3.60, CV=0.295), that pipeline disasters contributes to loss of properties (mean=3.75, CV=0.291), and pollution of air for human respiration (mean=3.86, CV=0.251), and that the it also leads to scarcity of food (mean=3.77,

CV=0.283).

4.3. Level of awareness about pipeline disaster amongst different stakeholders

Research question three sought to examine the level of awareness about pipeline disaster amongst different stakeholders.

Table 3. The level of human and ecological impacts of pipeline disaster in Nigeria.

Statements	N	Minimum	Maximum	Mean	Std. Deviation	Remark
Level of awareness about pipeline disaster	832	1	4	2.62	.856	High Level

Table 3 showed the level of awareness about pipeline disasters amongst the different stakeholders. The study showed that the different stakeholders are aware about pipeline disasters (mean=2.62, SD=0.856). This indicates a high level of awareness about pipeline disasters among the different stakeholders.

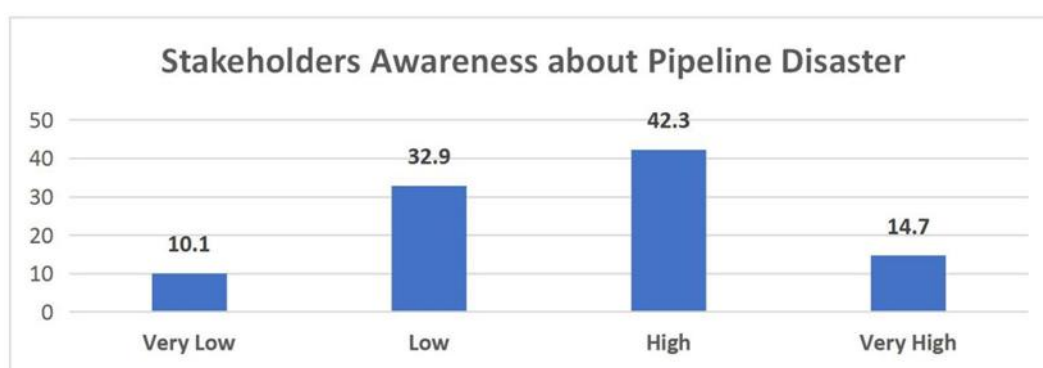


Figure 3. Level of awareness about pipeline disaster amongst different stakeholders.

Figure 3 present a pictorial view of the level of awareness amongst the different stakeholders. The chart showed that 14.7% of the stakeholders have a very high awareness about pipeline disasters, 42.3% of them have a high awareness about pipeline disasters, 32.9% have a low awareness about pipeline disasters and 10.1% of them have a very low awareness about pipeline disasters. This showed a high level of awareness about pipeline disasters among the different stakeholders.

4.4. Reliability test using cronbach's alpha

In this study, reliability testing was done through the use of Cronbach's alpha. [32] indicate that Cronbach's alpha with a value of greater than 0.6 is acceptable. This emphasis is maintained by [33] that the Cronbach's Alpha measures the inter-item consistency and it measures the coefficient that reflects how well items in a set are positively correlated to one another. They state that a Cronbach's Alpha measurements that are less than 0.6 are generally considered to be poor, however, those over 0.7 range are considered good; the closer the reliability coefficient gets to 1.0, the better. Cronbach's alpha for the three sets of variables analysed was found to range between 0.678 and 0.748. The data

collected for this research was considered to be internally stable and consistent. Details are presented in Table 4.

Table 4. Cronbach's alpha test results.

Sections	Item Groups	No. of Items	Cronbach's Alpha
Section C	Causes of pipeline disaster between year 2000 and 2019 in your area	6	0.678
Section D1	Human impacts of pipeline disaster	6	0.679
Section D2	Ecological impacts of pipeline disaster	6	0.748

As revealed in Table 4, a reliability analysis was done on all questions following a 5-point Likert scale questionnaire, where questions were categorized according to research themes. Causes of pipeline disaster between year 2000 and 2019 in the area produced a Cronbach's Alpha value of 0.678. This showed that the scale was acceptable for further multivariate analysis. Ecological impacts of pipeline disaster produced the highest Cronbach's Alpha value of 0.748. Human impacts of pipeline disaster produced Cronbach's Alpha value of 0.679. It was therefore proven that all three scales were sufficiently reliable for further analysis.

4.5. Test of normality

It important to check normality of data before embarking on Confirmatory Factor Analysis. The skewness and Kurtosis were adopted in this study to examine the normality of the data collected through field survey. It has been observed that there is lack of consensus among scholars and in different literatures on the cut off points for determining normality of data using skewness and kurtosis with a base of positive and negative sign of kurtosis and the skewness [34,35]. However, some scholars agree on absolute kurtosis values ranging from ± 2.0 to ± 7.0 and higher to be sign of non-normality of data set [34,36]. The normality test conducted for this study ranged between -0.607 to -1.182 for skewness and 2.226 to -0.307 for kurtosis (details in the appendix section). This indicates normality of the distribution and hence Confirmatory Factor Analysis can be carried out on the data set.

4.6. Correlation analysis between constructed factors

In order to stipulate the use and strength of the linear relationship that occurs between variables, a correlation analysis should be implemented; namely Pearson's product moment correlation coefficient (r) which is utilized for parametric statistics, and Spearman's Rank correlation for non-parametric statistics.

Table 5 presents a bivariate correlation matrix of the factors associated with each other. To interpret the correlation matrix values, the research applies Cohen's (1988) guidelines, which are: small ($r=0.10$ to 0.29), medium ($r=0.30$ to 0.49) and large ($r=0.50$ to 1.0). An investigation of the relationship between the overall factor variables using Pearson's correlation coefficient revealed that the values for the pipeline disaster (PD) ($r=0.07$, $p<0.05$), had a small but significant positive correlation with the ecological factor (EF). Also, a very small and insignificant negative correlation was found between pipeline disaster (PD) and the human factor (HF) ($r=-0.03$, $p>0.05$). In addition,

the correlation matrix results show that multi-cellularity does not exist among the variables since the correlation coefficients among them is not above 0.8 benchmark.

Table 5. Correlation analysis results.

		Pipeline Disaster (PD)	Ecological Factor (EF)	Human Factor (HF)
Pipeline Disaster (PD)	Pearson Correlation	1	.070*	-.003
	Sig. (2-tailed)		.043	.931
	N	832	832	832
Ecological Factor (EF)	Pearson Correlation	.070*	1	.084*
	Sig. (2-tailed)	.043		.015
	N	832	832	832
Human Factor (HF)	Pearson Correlation	-.003	.084*	1
	Sig. (2-tailed)	.931	.015	
	N	832	832	832

4.7. Model specification

The specification of the statistical model for the analysis was based on the following equation: $Y = \beta_0 + \beta_1 \text{Human} + \beta_2 \text{Ecol. \& Institut.} + \mu t$, where, Y =Pipeline Disasters; β_0 =intercept; Human =activities of vandals, sabotage, etc. $\text{Ecological \& Institutional}$ =corrosion, lack of maintenance, operational error, mechanical failure, etc; and μt is the error term. β_1 , and β_2 , are coefficients of the independent variables showing the magnitude of effects of the respective independent variables on the dependent variable (pipeline vandalism).

4.8. Confirmatory factor analysis (CFA)

In this study, three levels were adopted in carrying out the SEM analysis. They are; confirmatory factor analysis (CFA), measurement model and structural model. The first two are the preparation of data for SEM companies while the third is the complete SEM analysis. The CFA analyzes the relationship between the dominant's variables and their related indicators. The measuring model is a data preparation segment which evaluates standardization of the instrument measured. The calculation is also used in the study of CFA between the latent measures and their observed measures. The relation between latent and observed variables is explained in this article [37]. All factors with a cut-off point greater than or equal to 0.5 were selected and taken into account on the measuring model after review of all variables. The following recommended fitness indices given by [37] have been taken into consideration in deciding the quality-of-fit indices. This includes: normed chi-square, root mean square error of approximation (RMSEA), parsimony normed fit index (PNFI), comparative fit index (CFI), adjusted goodness of fit index (AGFI), parsimony comparative fit index (PCFI), test of close fit for p (PCLOSE). These fitness indices were calculated using the AMOS software.

Table 6. Measure model evaluation.

Metric/Statistic	Observed Value	Recommended value	Comments
<i>Absolute Fit</i>			
Normed Chi-Sq	3.107	between 1 and 5	Requirement Achieved
GFI	0.946	≥ 0.90	Requirement Achieved
RMSEA	0.05	≤ 0.060	Requirement Achieved
PCLOSE	0.448	≥ 0.050	Requirement Achieved
<i>Incremental Fit</i>			
CFI	0.895	≥ 0.90	Requirement Achieved
AGFI	0.93	≥ 0.80	Requirement Achieved
<i>Parsimonious Fit</i>			
PNFI	0.737	≥ 0.50	Requirement Achieved
PCFI	0.772	≥ 0.50	Requirement Achieved

From Table 6, it can be seen that the absolute fit of the model (RMSEA=0.05, Normed ChiSq=3.107 and PCLOSE=0.448), incremental fit (CFI=0.895, GFI=0.913, AGFI=0.93) and Parsimonious fit (PNFI=0.737 and PCFI=0.772) indicates a good model fit, as all the values met the required level of goodness-of-fit (GOF). Therefore, it assumed that the model is fit for structural analysis. This study conducted SEM to explore the structural relationship between human factors and ecological factors and pipeline disasters. Composite variables were created using factors from AMOS version 24. The data was imputed to derive the composite variables and they were used to create the composite model. The path diagram for the measurement model was presented in Figure 4.

4.9. Confirmatory factor analysis (CFA) with interaction

Confirmatory Factor Analysis (CFA) was adopted in this study to provide analysis on the relationship between the key variables (human factors and ecological factors and impacts of pipeline disasters) and their corresponding indicators.

From the model in Table 7 and Figure 5, the results generated indicated that pipeline disasters significantly contribute to ecological problems (such as water contamination, pollution of soil by hydrocarbons, environmental pollution/degradation, destruction of farmlands, destruction of aquatic ecosystem and loss of vegetation) in Nigeria (Coefficient=0.269, CR=5.634 & P value=0.000). The study also revealed that pipeline disasters contribute significantly to human related problems such as loss of lives and properties, pollution of air for respiration, adverse health effects on humans, scarcity of food as well as increase in the price of drinking water and other essential commodities in Nigeria (Coefficient=0.543, CR=7.236& P value=0.000).

Table 7. Structural equation (Model).

			Estimate	S.E.	C.R.	P
Pipeline Disaster	<---	Ecological Impacts	0.269	0.048	5.634	***
Pipeline Disaster	<---	Human Impacts	0.543	0.075	7.236	***

Note: *** indicate variable significance at 1%.

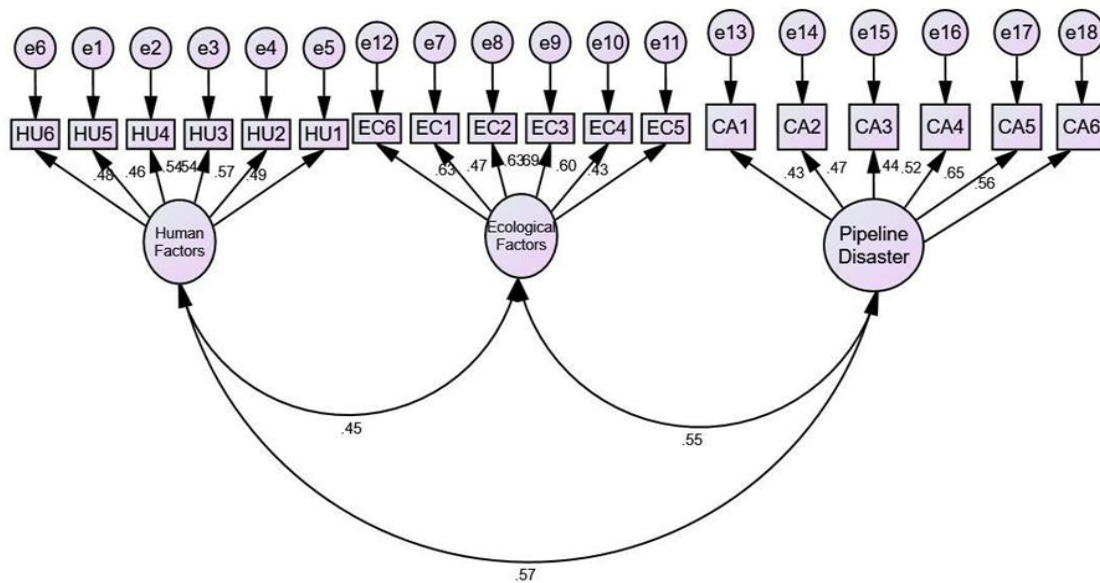


Figure 4. Measurement model for the study.

Note: CA inputs represent impacts of pipeline disaster, HU inputs represent human impacts and EC input represent ecological impacts of pipeline disaster.

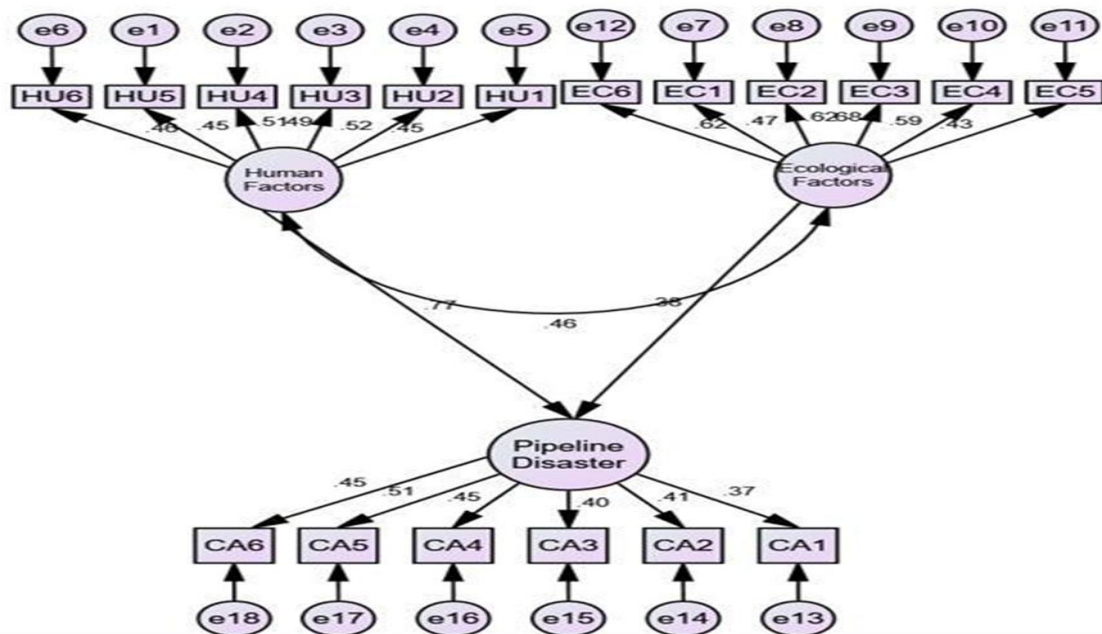


Figure 5. Estimated structural model.

4.10. Hypotheses testing

H0₁: Pipeline disasters does not have significant impact on human

This hypothesis was related to the examining human impacts of pipeline disasters in Nigeria. At a significant level of 5%, the p-value for human impact is (Coefficient=0.078, CR=6.965 & P value=0.000), indicating that pipeline disasters have statistically significant impacts on humans in

Nigeria. In addition, it can be concluded that pipeline disasters have significant impacts on humans in Nigeria.

Hence, H_0 is rejected.

H₀₂: Pipeline disasters does not have significant ecological impacts

The second hypothesis relates to testing the probability of ecological impacts of pipeline disasters in Nigeria over the period of the study. At a significant level of 5%, the level of significance is (Coefficient=0.083, CR=6.799 & P value=0.000). Therefore, it can be concluded that pipeline disasters have huge ecological impacts in Nigeria. Thus, the null hypothesis is also rejected.

5. Discussion

The study carried out examine the level of awareness of stakeholders on the immediate and remote causes of pipeline disasters in Nigeria. Primary data was used through the use of questionnaires.

5.1. Causes of pipeline disasters in Nigeria between years 2000 to 2019

The study reveals that, all of the causes aforementioned frequently influenced pipeline disasters, and activities of vandals has the highest influence on pipeline disaster. Activities of vandals have a more agreement with highest mean value. Also, having no community-based security to monitor the pipelines was observed to be a contributing factor to pipeline disaster due to the fact that most pipelines are not well secured which make them vulnerable to pipeline vandalism and in turn lead to pipeline disasters in most cases. Lack of adequate maintenance of pipes, joint and valves as well mechanical failure and operational error were also observed to contribute to pipeline disaster in Nigeria. This finding is in line with and Onuoha [16] where it was found that lack of adequate maintenance of pipeline and exposure of pipeline to erosion can easily cause pipeline explosion. Evidence have shown that despite the used of security agencies such as Nigeria Security and Civil Defense Corps (NSDC), the special military, the joint task force (JTF) and the police the vandals still carry out their activities without much challenge. Equally, the number of militants prosecuted and jailed over vandalism seems to be difficult if not impossible. This is due of lack of community-based security team to monitor the pipeline especially when the vandals have the support of the locals from the region and community heads who can easily be bribed to frustrate prosecution of vandals.

5.2. Assessing the human and ecological impacts of pipeline disaster

On human and ecological impacts of pipeline disaster, both factors have been affected negatively as a result of pipeline disasters. It can be concluded that the environment (ecology) was observed from the study to have suffered more as a result of pipeline disasters. Human impacts resulting from pipeline disasters are very significant in Nigeria. Hence, we reject the hypothesis that pipeline disasters do not have significant impact on humans. Also, ecological impacts resulting from pipeline disasters have been extremely significant in Nigeria. The null hypothesis is also rejected as it can be concluded that ecological impacts of pipeline disasters are more severe in Nigeria. This finding is in line with [38] where it was found that the effects of the pipeline fire in the study area are both direct human and ecological. The direct human effects include the reported cases of health

problems, forced emigration and destruction of the livelihood in the affected community. The impact of these direct human effects can be severe on the people, especially in countries (such as Nigeria) where insurance for medical treatment and loss of livelihood, or any other welfare systems unavailable for most populations (Cardona 2003). Ecological effects showed in this study include significant loss of the vegetal (by about 22% of the heavy forest and 15% of light forest) and the exposure of the land surface to erosion and landslide (445.5 ha). There was also destruction of many animal and human habitats by the pipeline fire.

5.3. Level of stakeholder awareness of pipeline disasters

On the level of awareness of pipeline disasters and the collaboration of the Stakeholders, the study revealed high level of awareness about pipeline disasters among the different stakeholders (see Figure 1).

6. Conclusion

African nations are experiencing rapid economic growth and development, particularly within the energy sector; however, this growth has come at a cost to the environment and society. Nowhere have these impacts been felt more precisely than in the oil and gas producing regions of Nigeria where years of neglect and mismanagement have resulted in pipeline disasters. Based on the findings of this study, it is concluded that;

- i. Causes aforementioned frequently influenced pipeline disasters, and activities of vandals has the highest influence on pipeline disaster. Also, having no community-based security to monitor the pipelines was observed to be contributing factor to pipeline disaster due to the fact that most pipeline are not properly secured which make them vulnerable to pipeline vandalism and in turn lead to pipeline explosion in many cases. Lack of adequate maintenance of pipes, joint and valves as well mechanical failure and operational error were also observed to contribute to pipeline disaster in Nigeria.
- ii. Human impacts resulting from pipeline disasters are very significant in Nigeria. Also, ecological impacts resulting from pipeline disasters have been extremely significant in Nigeria. It can be concluded that ecological impacts of pipeline disasters are more severe in Nigeria.
- iii. There is high level of awareness of pipeline disasters among the different stakeholders.

Based on the analysis discussed, the following recommendations are made so as to help the stakeholders' collaboration in mitigating losses during oil pipeline disasters in Nigeria.

- i. Having observed that the ecological impacts of these disasters are very severe, immediate clean-up of oil spills in all the affected regions is recommended.
- ii. In addition, improvements in the provision of good infrastructure such as road network, hospitals, electricity, and portable water supply reduction in land degradation will bring an end to militancy and sustain lasting peace in the region with less compensation. Also, preference should be given to good governance and accessibility for the training of ex-militants. Finally, there will be significant reduction in the costs of maintenance of crude

oil pipelines if the stakeholders including government will consider the findings of this research study and implement with utmost sincerity.

- iii. Concerning the awareness level, more efforts are required to enlarge involvement and the awareness level of the citizens accompanied by the increased responsibility of the stakeholders would support the agility and the effectiveness of the problem. The improved local responsibility under coordination of the stakeholders would help at the beginning of the way for the excellence of the system. The most important goal must be to build a pipeline disaster-resilient community in Nigeria.
- iv. This study also advocates for improved tracking system, public-private participatory monitoring of the pipelines, strict enforcement of the right-of-way regulations and other planning policies, as well as creation of awareness on the disastrous effect of pipeline leakage when it is not reported. We also recommend improvement in post-disaster recovery processes and improved insurance policies in Nigeria and other developing countries.
- v. Lastly, vigorous public enlightenment campaign be mounted in these communities to dissuade and educate them on the inherent dangers of pipeline vandalization. It is an illegal act and the scale of destruction both in terms of health and ecological standpoint far outweighs whatever pecuniary gains it may tend to offer. Effort should also be made to provide the youths with employment, infrastructural facilities like skill acquisition centres and the necessary economic empowerment tools for self-actualization.

Data availability

The data (in converted form) is hosted on a GitHub repository <https://www.github.com/dataforpipeline>

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A: Normality Test

	Variable	min	Max	skew	kurtosis
Causes of Pipeline Disasters	CA6	1	5	-0.718	0.318
	CA5	1	5	-0.645	0.033
	CA4	1	5	-0.757	0.367
	CA3	1	5	-0.622	0.22
	CA2	1	5	-0.75	0.479
	CA1	1	5	-0.87	1.309
Ecological Impacts	EC6	1	5	-0.801	0.034
	EC5	1	5	-0.839	0.46
	EC4	1	5	-0.837	0.085
	EC3	1	5	-0.607	-0.307
	EC2	1	5	-0.706	-0.148
	EC1	1	5	-0.695	0.434
Human Impacts	HU6	1	5	-0.876	0.608
	HU5	1	5	-0.911	0.702
	HU4	1	5	-0.96	0.788
	HU3	1	5	-0.754	0.564
	HU2	1	5	-1.147	1.479
	HU1	1	5	-1.182	2.226

Appendix B: Covariances: (Test of Hypothesis)

			Estimate	S.E.	C.R.	P	Label
Human_Factors	<-->	Ecological_Factors	.079	.012	6.529	***	
Ecological_Factors	<-->	Pipeline_Disaster	.078	.011	6.965	***	
Human_Factors	<-->	Pipeline_Disaster	.083	.012	6.799	***	



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