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Sources and effects of environmental pollution from oil and gas industrial operations

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Abstract

Fossil fuel which is the world's major source of energy is desperately sort for globally. The economic and social benefits of exploiting this natural resource sometimes relegate the environmental consequences to the background. The environmental degradation in oil and gas producing communities emanating from oil and gas operations is therefore discussed in this paper. The study shows that all the three streams of the petroleum sector generate some form of pollutants that affect every component of the environment. Some sources of pollution are exploration activities, gas flaring, oil spillage, accidental explosions, produced formation water, produced formation fines and sands, drill cuttings, drilling fluids, effluents and waste discharges from refineries. The environmental damages caused by these pollutants affect humans, plants, animals, the ecosystem, climate and infrastructure. Other impacts include social problems and economic losses to host communities that depend on the environment to eke out a livelihood. It is not morally right to sacrifice environmental safety for economic benefits, the dilemma needs to be properly handled and priorities should be rightly set. Responsible hydrocarbon exploitation cannot be over emphasized because environmental protection and preservation for continuity of life is a duty and should be every one's business.

Keywords: Petroleum, spillage, drill cuttings, reservoir, produced water.

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1. Introduction

The oil and gas industry is a major sector of the world's economy because it is the main source of global energy. The revenue generated through operations in oil and gas activities has sustained the economy of many nations which has resulted in considerable increase in oil and gas exploration, production, refining and marketing. Petroleum products have been serving as feedstock for production of several consumer goods. The benefits of oil and gas production are no doubt invaluable, but this is not without demerits, there is an ugly side of the story that has subjected host communities to the consequences of pollution and environmental degradation. In fact, it is estimated that nine million people die annually from the impact of pollution which represents 16% of all deaths worldwide [1], and oil and gas activities is a major contributor to environmental pollution. In the event of an accidental explosion, though rare, the disaster is usually fatal and enormous [2]. Thus, this paper discusses the environmental issues that have emanated from oil and gas production activities and the dilemma facing host communities especially in Africa. There are different forms of pollution; land, water, air noise and light pollutions. The contribution of the petroleum industry to these forms of pollution is also reviewed. The three major sectors in the oil and gas industry are the upstream, midstream and downstream sectors as presented in Figure 1.

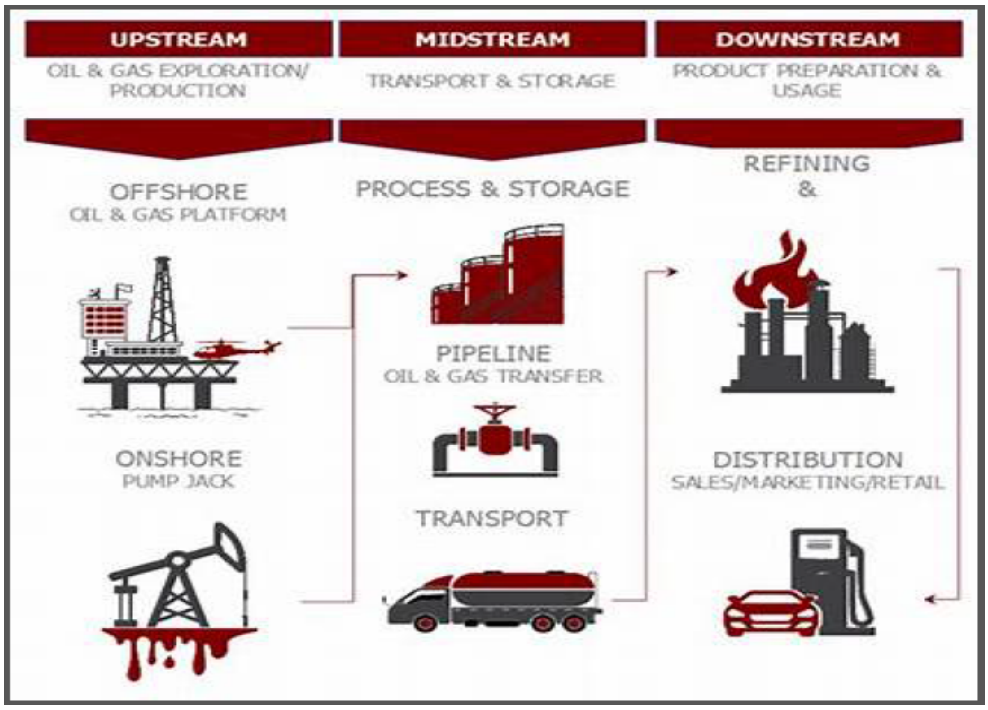


Figure 1: The Three Sectors of the Oil and Gas Industry

The upstream sector comprises of exploration and production activities carried out in locating, developing and producing oil and gas. The midstream sector mainly involves processing, storage, transporting and marketing of the produced crude oil and natural gas. The downstream operation involves all the activities of converting the raw crude oil and natural gas to useful petroleum products.

This part of the industry concentrates on crude oil refining and natural gas processing and it also includes activities of the petrochemical industry that transforms petroleum products to consumer goods [3]. Distribution and marketing of petroleum products also belongs to the downstream arm of the oil and gas industry. All the different operations in the upstream, midstream and downstream sector of the petroleum industry generate some form of pollution that impacts on the environment. The impacts are felt locally and globally by all the biotic and abiotic components of the environment [4, 5, 6, 7]. These different forms of pollution have raised environmental concerns amongst government regulatory agencies, oil company operators, host communities, activists, scholars and environmentalists. Peaceful and violent protests by host communities have been used to expressive resistance to this menace. It is therefore necessary to strike a balance between the benefits that accrue from oil and gas activities and the environmental impacts it induces on host communities, this is a dilemma that has to be handled objectively.

1.1 The Environment and Its Importance

Environment is defined as the total surrounding which includes natural and biological resources, human resources and their interaction with each other. Other aspects of an environment includes human activities, biophysical components and natural processes of land, water, air, layers of the atmosphere, organic and inorganic matters, living and non-living components of the environment. It also includes processes of the human environment such as technology, culture, administration, history, archaeology, structures, resources, health, nutrition and safety [8]. Other features are the socio-economic elements of the environment, external factors that shape the existence of a population, and factors that provide conditions for development, growth, danger and damage. Therefore, environment has everything to do with the existence and continuity of life for man and other living and non-living components since anything that affects an environment ultimately affects population. Figure 2 shows the multiple and inter related effects of pollution on different components of the environment.

Environment plays a vital role in healthy living and existence of life on earth; it is nature's gift to living things. The earth and its environment are home to the human race, different species of plants, animals, microorganisms and inanimate things; it provides food and sustenance to all forms of life on earth and the ecosystem. Humanity's entire life support system depends on environmental factors and conditions. Environment is the primary pathway to human, animal and plant exposure to pollutants, thus, environment occupies a strategic position to sustainability. Improving the quality of the environment can promote good health and sustainability, necessitating that all forms of pollution that degrades the earth and its environment be studied, controlled and prevented if possible.

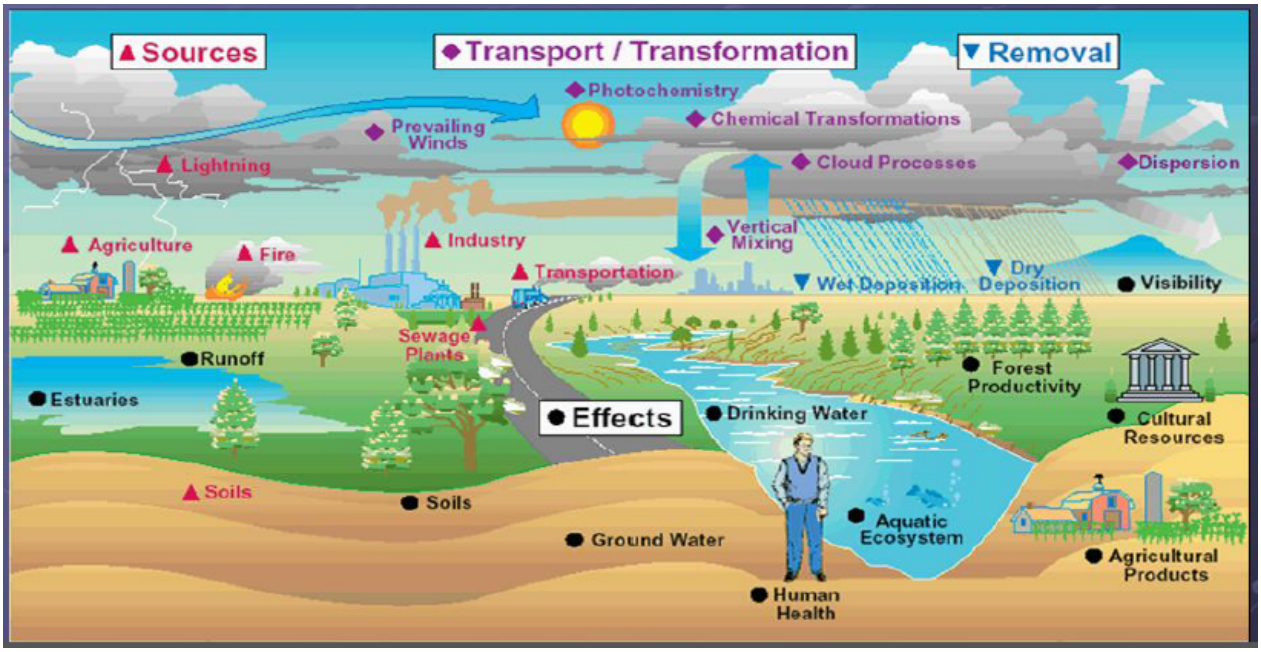


Figure 2: Effect of Pollution on Different Components of the Environment

Environmental risks are not evenly distributed across boarders; it is mainly dependent on man's activities, especially industrialization. Industrialization has increasing jeopardized environmental serenity hence the relationship between humanity, industrialization and environment needs to be balanced. Industries that have played key roles in global pollution are the petroleum, coal, mining and chemical industries. Agriculture which is a means of human sustenance is also a source environmental pollution. In this paper however, the focus is on sources of environmental pollution emanating from the petroleum industry as well as its effects on elements of the environment.

Environmental pollution is a major demerit associated with the oil and gas industry. This is because at every stage of operation and in all the sectors, pollutants such as chemicals, oil and grease, gases and effluent discharges are released into the environment. These pollutants directly or indirectly affect the environment and such effects range from physical to chemical and biological damage. Some of the environmental damages in typical oil producing regions such as the Niger Delta have been discussed and such hazards has led to hardship and poverty for host community dwellers [9-14]. Impacts on the environment due to accidents, oil spills and blowouts can be very disastrous and the effects can last for a long time, sometimes even for decades which poses a serious threat to continuity of life. In extreme cases, some very sensitive animal and plant species go extinct. A polluted atmosphere contaminates rain water quality which falls below approved standards, thus limiting use of rain water [15]. This is harmful to human existence and endangers the ecosystem, species of plants, animals and micro-organisms. The effects on the abiotic elements of the environment include a gradual dilapidation of infrastructure, and

can cause ground surface subsidence due to fluid extraction over time if such extractions are not replenished.

2. Major Sources of Environmental Pollution from Oil and Gas Activities

There are different sources of environmental pollution from various stages of oil and gas operations. The exploration, production, processing, storage, marketing and distribution of oil and gas are capable of causing significant changes in the environment. The hazardous compounds in air pollutants that are associated with upstream operations in the oil and gas industry have been identified and discussed in various literatures [16, 17]. The extent of impact depends on the process, size, nature, complexity of project, effective planning, sensitivity of environment, and pollution control techniques [18]. A summary of the major sources of pollution, the pollutants and the affected environmental components are presented on Table 1 and each of these sources is briefly discussed.

2.1. Seismic Survey

Noise is most often defined as unwanted sounds. During seismic data acquisition, vibrations and noise pollution is the main environmental problem creating surface and sub-surface disturbances. The noise is quite enormous, disturbing humans, wildlife and sea animals. Acoustic pollution has effect on marine animals and fishes; research has shown that about fifty five marine species including twenty commercially viable species of fish are endangered as a result of noise pollution [19, 20]. Even humans are affected by generated noise and vibrations from oil and gas operations; potential health risks include annoyance, headache, hearing impairment, sleep disturbance and cardiovascular diseases [21]. It has been reported that the noise generated during oil and gas activities cannot be reduced below the residential permissible noise level using current wall mitigation strategies [22].

2.2. Disposal of Drill Cuttings, Drilling Fluids and used Chemicals

Drilling creates substantial quantities of drilling wastes composed of rock drill cuttings, drilling fluid, and a wide range of chemical additives [23, 24, 25, 26]. The major constituent of drill cuttings is formation debris which sometimes contains heavy metals and radioactive elements and it constitutes land pollution when disposed on land without treatment. Barite and bentonite clays are the major composition of water drilling mud and after use needs to be disposed. When dumped on the land, they prevent plant growth until natural processes lead to development of new topsoil. In water, these materials disperse and sink, burying and killing marine life, thus leading to loss of biodiversity.

The environmental effect of oil based mud disposal is more serious and as such requires careful handling. Disposal of large quantities of drilling fluids can change the acidity or salinity levels of soil and water and it increases the turbidity of water bodies. The chemicals and sludge generated during drilling include

oily residues and obsolete chemicals, which if not properly treated and disposed carry high pollution and health risks. In fact, it has been speculated that many chemicals used during the fracturing and drilling stages of oil and gas operations can have long term health effects [27].

Table 1: Major Sources of Environmental Pollution from Oil and Gas Operations

Oil and Gas Operation/Activity	Source(s) of Pollution	Pollutant(s) and Problem	Affected Environment	Affected Biotic and Abiotic Components
Exploration	Seismic Survey	Noise from sub-surface explosions	Land and water bodies	Humans, aquatic and terrestrial lives
Drilling	Drill cuttings	Disposal of formation debris	Land and water bodies	Plants, aquatic and terrestrial lives, organisms and ecosystem
	Drilling fluids	Disposal of used drilling mud		
	Chemical additives	Disposal of used chemicals		
	Formation	Oil, gas and formation water		
Production	Gas Flaring and venting	Smoke, CO_2, heat, noise, acid rain, night light, soot, particles and other toxic substances	Land and water bodies (through acid rain), and the atmospheric air	Humans, plants, aquatic and terrestrial lives, organisms, ecosystem, climate, ozone layer and infrastructure
	Accidental crude oil spills from tankers, barges, storage facilities, pipeline leakages, sabotage and transportation	Crude oil and volatile organic compounds (VOCs)	Land and water bodies	Humans, plants, aquatic and terrestrial lives, organisms, ecosystem, social and economic life
	Accidental explosions and blowouts	Oil, natural gas, fire, heat, smoke, CO_2, CO, VOCs and other toxic gases	Land, water bodies, air and atmosphere	Humans, plants, aquatic and terrestrial lives, organisms, ecosystem, climate and infrastructure
	Reservoir formations	Produced water disposal	Water bodies	Aquatic plants, animals and ecosystem
		Disposal of produced sand and fines, and Subsidence	Land	Plants and terrestrial animals and organisms
Oil Refining and Gas Processing	Refinery	Disposal of effluent liquid and gaseous waste, and used chemicals	Land, water bodies and atmosphere	Humans, plants, aquatic and terrestrial lives, organisms and ecosystem
Transportation	Accidents and explosions from oil tankers and barges at sea	Oil, fire, heat, smoke and toxic substances	Land, water bodies and atmosphere	Humans, plants, aquatic and terrestrial lives, organisms and ecosystem
Other Activities	Deforestation, and construction of infrastructure	Dust, noise and bio-diversity loss	Land and water bodies	Plants, animals and ecosystem

2.3. Oil Spillage

Major sources of crude oil spillage and spills from refined petroleum products and by-products include leakages from corroded and damaged pipelines, storage facilities, accidents and sabotage. Oil spill can

occur on land from drilling of oil wells, during loading operations, from oil tankers and during transportation and marketing. Oil is often spilled into the ocean or coastal waters, rivers and streams from leaking, corroded or damaged barges, offshore platforms, drilling rigs and wells, and from used or waste oil. Oil spillage is detrimental to marine life, coastal vegetation, terrestrial habitats, plants and animals; it destabilizes ecosystems and leads to loss of soil fertility [28, 29, 30]. It causes instant death of marine life, reduces wildlife population and poses risks of explosions and fire outbreak in the environment [31]. In some cases the underground water resource is affected which poses a threat to human health. Additionally, the socio - economic livelihood of host communities are affected [32] and human health is also at risk on consumption of oil contaminated sea foods such as fish, prawns and vegetables.

There have been many large scale incidences of oil spillage in many oil producing communities in Africa. In many instances, the oil spills are rarely promptly cleaned which leads to spreading. Evaporation of volatile low molecular weight gaseous and liquid components occurs and contaminates the atmosphere which affects aerial life. Some oil fractions that dissolve in water get oxidized, while some undergo bacterial changes and eventually sink to the bottom by gravitational action, resulting in emulsified water which affects aquatic life. It has been reported that oil polluted areas contain higher concentrations of heavy metals than unpolluted soil [33]. The toxicity and unprecedented damage done to fauna and flora by oil spillage have long term effects and have caused agitation and concern in rural oil producing communities.

2.4. Gas Flaring

Gas flaring is the deliberate burning of associated gas produced during oil production as a means of disposal. This act creates a ceaseless, high intensity flame and heat, subjecting the environment to twenty four hour light and introduces pollutants into the atmosphere which affect all living things especially aerial life. The atmospheric air is often contaminated with unwanted gases, smoke, particles and other toxic substances. Air pollution is the presence in the outdoor atmosphere of one or more contaminants such as dust, fumes, gas, midst, odor, smoke or vapor in quantities, characteristics and duration that render harm or are potentially injurious to human, plant and animal life or property, or which unreasonably interfere with the comfort of life [34]. In 2012, air pollution was reported to be the single largest environmental health risk globally that accounted for more than seven million deaths especially in developing countries [35].

Gas flaring which is an ugly practice in some developing countries is a significant source of air pollution and greenhouse gas from the oil industry [36, 37]. Gas flaring releases pollutants into the air and these pollutants include sulphur oxides, nitrogen oxides, carbon disulphide, carbonyl sulphide, carbon dioxide,

carbon monoxide, volatile organic compounds, particulate matter, hydrocarbons, ash, photochemical oxidants, hydrogen sulphide and black soot [38, 39, 40, 41]. A large volume of carbon dioxide is produced during gas flaring as waste product, worsening the greenhouse effect dilemma. Gas flaring also gives rise to acid rain which is primarily caused by emissions of sulphur dioxide (SO_2) and nitrogen oxides (NO) that combine with atmospheric moisture to form sulfuric acid and nitric acid respectively. In addition, acid rain speeds up the decay of building materials such as paints. Prior to falling to the earth, SO_2 and NO_2 gases and their particulate matter derivatives of sulfates and nitrates, degrade the environment, causing low visibility and thus harming public health.

Acid rain acidifies lakes, streams and the soil, hence depleting soil nutrient and damaging vegetation [42]. Research has shown that the nutritional values of crops within such vicinity are reduced and in some cases could lead to total loss of vegetation in the immediate surroundings of the flare due to tremendously generated heat and acidic nature of the soil pH [43]. Associated with gas flaring also is light pollution which subjects living organisms around the vicinity of the flare to twenty four hour light, hence, it impairs night-time patterns in animals. Gas flaring affects reproduction of fishes, drives away fishes to deep sea areas and also drives away organisms that fishes feed on, thereby disturbing the food chain and ecosystem. This makes it difficult for local fishermen by pushing them far into remote and unfriendly marine areas in search of fish due to scarcity of fish around the shores. This leads to shortage and high cost of marine foods.

2.5. Disposal of Produced Water

Hydrocarbon production from reservoirs under water drive is often accompanied with produced formation water after a period of time. The problem of produced water management and disposal is thus created. Produced formation water is often disposed into water bodies after treatment, but it has been observed that such treatments fall short of the required standards, hence causing water pollution. Produced formation water is not environmentally friendly because it contains elevated levels of dissolved ions, salts, hydrocarbons, heavy metals and other trace elements. Its environmental impact has been reported since the mid-1800s when the first oil and gas wells were drilled and operated. The most common concerns include degradation of soils, ground water, surface water and ecosystems [44, 45]. Thus, formation water disposal poses a big challenge especially because the volume involved most times is huge and spans over a long period of time. Most oil companies especially in developing countries discharge treated produced water directly into nearby water bodies which of course is not an environmentally healthy practice. A better option is direct re-injection of produced water back into the formation from where it is produced, but this option is not always deployed because it is capital intensive.

2.6. Disposal of Produced Formation Sand and Fines

Fines migration from unconsolidated hydrocarbon reservoir formations during oil and gas production eventually result in surface production of tons of formation fines and sand. Disposal of produced sand and fines is of environmental concern because produced sand and fines contain radioactive elements and heavy metals just like the formation water surrounding it. This has attracted strict disposal regulations to ensure environmental safety, thus making disposal of produced fines and sands expensive. Creation of cavities underground by solid particles removal could result in rearrangement of the formation structure to fill up the created voids. Such adjustments can result in subsidence on the earth's surface after many years of formation sand and fines removal just like dredging activities do. This kind of environmental degradation can undermine the integrity of structures on the earth's surface which has long term environmental consequences.

2.7. Disposal of Effluents and Waste Discharge from Refineries

Refining and petrochemical operations produce an array of complex gaseous, liquid and solid effluents into the environment. These toxic chemicals which constitute land, water and air pollutants include carbon dioxide, carbon monoxide, nitrogen oxide, spent catalysts, benzene, chlorinated hydrocarbon, particulates, carbon black, oil sludge, xylene, mercury, chromium, etc. Sea foods such as fishes can consume and store mercury in their brains for a long time and can easily pass this into the human food chain, resulting in adverse effects on the human population. Liquid refinery effluents usually contain oil and grease. These compounds contain organic chemicals such as phenol cyanide, sulphide-suspended solids, chromium and biological oxygen demanding organic matter which pollute land and water bodies on disposal. Sludge and other lethal chemicals removed from the bottom of oil storage tanks in the course of maintenance activities are also disposed in the environment [46]. Lubricating oils and other wastes in the form of sludge, bitumen, oil, sand and sediments are present in large quantities within oil flow stations, storage terminals and tanks [47]. Discharge of refinery effluents into water bodies and land devastates the environment and threatens living things. Some residues from crude oil refining such as carbon black and tar that can constituent waste materials need to be put to good use to avoid environmental pollution.

2.8. Other Sources

Some other environmental pollutants from oil and gas activities are dust emissions, noise pollution and other forms of pollution from earth moving equipment, vehicles, well completion, well testing and drill rig exhausts. The pollutants include particulates, oxides of nitrogen, carbon monoxide, sulfur dioxide, volatile organic compounds, and untreated waste water. Transportation, distribution and marketing of

petroleum and petroleum products also cause significant pollution such as discharge and leakage of oil from storage tanks and tankers on transit. Buried oil and gas pipelines under the ground reduce land use and pose environmental dangers. Deforestation reduces oxygen generation from plants and increases atmospheric CO_2. Gas venting to release pressure and ensure safety in production facilities introduces toxic gases into the environment. Construction activities generate dust, destroy natural habitats and increase noise intensity. Illegal petroleum refining creates massive environmental pollution on water bodies, land and air. Community crisis, insecurity and agitations over benefit allocations that accrue from oil and gas production to a community creates social vices, political struggles and violence that sometimes result in massive destructions [48, 49]. All these activities introduce pollutants into the air, land and water bodies.

3. Effects of Pollution from Oil and Gas Operations

Operations in the petroleum sector create environmental pollutions in an unprecedented scale which contribute in land, water, air and noise pollutions. Globally, every oil and gas producing community suffers some form of environmental pollution but preventive measures aimed at reducing the effects to the barest minimum should be the objective of all stakeholders involved. A typical example of a community that has suffered massive environmental degradation from oil and gas activities is Ogoniland in the Niger Delta region of Nigeria [5]. The effects of pollution from the oil and gas industry range from health to social, economic, infrastructural and environmental degradation. The damaging effects of environmental pollutions that emanate from oil and gas operations are therefore worth considering.

3.1 Effect on Human Health

Pollutions from oil and gas activities cause damage to human health in many ways. Crude oil is a complex mixture of different kinds of organic compounds, many of which have been found to be highly toxic and carcinogenic. It is composed of aromatic compounds such as benzene, ethylbenzene, toluene, xylenes and poly aromatic hydrocarbons (PAHs). Research conducted from field and laboratory experiments have shown that aromatic compounds are associated with leukemia. The compounds have also been reported to lower the count of white blood cells and are related to other blood and immune system diseases within five to fifteen years of exposure [50, 51]. PAHs have been linked to incidences of lung, skin, and bladder cancers, and drinking crude oil polluted water has been traced to hemorrhagic tendencies [52, 53]. Volatile components of crude oil have been found to aggravate asthma, bronchitis and escalated aging of the lung [54]. Other possible health effects are liver, kidney and spleen problems, lipid peroxidation, protein oxidation, lung damage, skin problems and deformities [55, 56].

Gas flaring contaminates rainwater which rural dwellers use for domestic activities and in some regions

where getting portable drinking water is challenging, rural dwellers often consume polluted rainwater which is very unhealthy. Nitrite content in rainwater above the required level which is often accelerated by gas flaring is specifically toxic to humans. The presence of high level of nitrite in the blood stream can cause methaemoglobinaemia, where the nitrite oxidizes haemoglobin to methaemoglobin. The Fe^{2+} present in the haem group is oxidized to its Fe^{3+} form and the remaining nitrite binds firmly to the oxidized haem. According to World Health Organization Guidelines for Drinking Water, the Fe^{3+} form does not allow transportation of oxygen, which results in methaemoglobinaemia and can lead to cyanosis. A study conducted with one hundred samples of rain water obtained from the Niger Delta region of Nigeria shows that human consumption of rainwater in gas flaring regions is very detrimental to health due to high nitrite content above the approved standard [57]. Gas flaring has been identified as the major cause of respiratory infections and other health issues such as asthma among rural dwellers who live close to flare sites [58-61]. Compounding the plight of rural dwellers is the generated heat from flare stacks that are in close proximity to residential areas, making life uncomfortable and unbearable for inhabitants in such localities. The air pollution arising from gas flaring therefore reduces quality of health and life, lowers life expectancy and promotes environmental degradation.

3.2 Effect on the Ecosystem

An ecosystem is a community of living organisms (plants, animals and organisms) interacting with other components of the environment (air, water, minerals, soil and other living organisms). The water habitat and its organisms is one ecosystem that is badly affected by oil spills. On water surfaces, floating oil films prevent natural aeration of the water body and this leads to death of fresh water organisms and marine life, leading to disruptions in the food chain. After a spill, sea animals and organisms gulp spilled oil or other food materials impregnated with oil, and it takes about five to fifteen years for regeneration to occur which happens at a very slow rate [62]. It has been reported that the presence of crude oil in water bodies at a concentration of about 4000 parts per million destroys fishes [63]. Research has shown that loud noise which is frequently associated with drilling and seismic activities disrupts chorusing in black drum fish, a behavior that is essential to breeding in commercial quantity [64].

Several studies have been conducted to investigate the effect of crude oil on rats. Results show that crude oil ingestion by rats can adversely affect reproduction and essential organs of the body such as the liver, kidney, renal and hepatic cells [65-70]. It also induces nephrotoxicity, oxidative stress, endocrine disruption, promotes infertility and can interfere with the normal growth process of a developing fetus during pregnancy [71-77]. Experiments have indicated that heavy metals in crude oil can be absorbed into the blood stream of animals through the skin by consistent exposure to it [78] and it is highly toxic with potential damaging agents to the haemopoitic system which can cause anemia [79]. It has also been

experimentally observed that as the concentration of crude oil increases in the system, the red and white blood cell counts reduce, showing that the exposure of animals to crude oil has toxic effects on the haematological parameters of animals and fishes [80]. Hence oil spill poses a threat to the ecosystem of which animals, fishes, microorganisms and the food chain are all endangered.

Accidental spill of oil and some other materials like brine, drilling mud and produced waste water contaminate the soil and could lead to inability of the soil to support plant growth. Generally, oil spillage is detrimental to crop yield [81-84]. Spillage on land causes films of oil to infiltrate the leaves of plants and other economic trees through their pores and roots, and this prevents the processes of photosynthesis and evapo-transpiration from occurring [85]. The infiltrated oil also causes the darkening of leaves and these patches of dark oil cuts off sunlight from the leaves and when the shielding of sunlight becomes too much, the leaves shrink off and the plant eventually dies [86].

Gas flaring has negative effects on the immediate environment as it adversely affects soil fertility, plant growth and wildlife. It generally reduces growth potentials of plants and reduces the quality of farm crop as the size and shape of traditional staples such as cassava, yam and plantain have been reported to be adversely affected [87-90]. Acid rain which is a problem caused by gas flaring has led to loss in biodiversity with destruction of forest and economic crops. Some rain forests have been reduced to grasslands dominated with shrubs, and the effect of acid rain has been observed to decrease in distance from flare sites [91, 92]. The heat generated from gas flaring destroys vegetation and mangrove swamps, and it suppresses growth and flowering of some plants, inducing soil degradation and diminishes agricultural productivity [93, 94]. Studies have shown that there is a direct relationship between gas flaring and productivity decline in agriculture, species compositions of vegetation and aquatic lives which are all adversely affected [95-97]. It also affects aquatic fauna and flora, leading to a reduction in fishery. The effect of light pollution from close proximity of gas flare stacks to forests and waterways adversely affects terrestrial animals, aquatic animals and other organisms. Across the oil producing communities, the night sky is lit up by flares, which during the rainy season reflect brightly from the clouds. It is difficult to differentiate between night and day because of the polluted air and burning light which disturbs nocturnal animals, driving them away from the area. Gas flaring, noise vibrations and soil contamination with waste disposal from refineries cause environmental pollutions that pose as threats to ecosystems [98]. A number of activities in the petroleum industry which are environmentally destructive degrade the environment.

3.3 Effect on Climate Change resulting from Global Warming

Gas flaring has affected the climate adversely, contributing to climate problems. The World Bank [99] shows that gas flaring has been the singular highest contributor to climate change; it has increased atmospheric temperature thus accelerating climate change. Global warming is the continued build-up of greenhouse gases in the atmosphere. These gases, which include carbon dioxide, methane, nitrous oxide and chlorofluorocarbons, block some of the heat radiated from the earth to cause a greenhouse effect. According to the inter-government panel on climate change, the last two decades of the 20th century were the hottest on record [100]. Greenhouse gases such as methane and carbon dioxide emitted from gas flares has contributed to global warming and this has led to a rise in sea level. Rising sea level mostly affects low-lying vulnerable areas like the Niger Delta, making it prone to flooding. Global warming also leads to soil erosion, flooding and drought.

The ozone layer is basically found at a height of about twenty to thirty kilometers above sea level. The ozone layer provides a protective layer like a blanket over the earth and it prevents the penetration of the sun's harmful ultraviolet rays from reaching the earth. Atmospheric pollution with chlorofluoro carbon (CFCS) gases cause depletion of the ozone layer which allows dangerous ultraviolet rays from the sun to reach the earth. Some skin diseases and low productivity in agriculture are caused by ultraviolet rays [101]. An increase in ultraviolet radiation affects water bodies and disturbs aquatic lives, causing death of aquatic organisms that support the food chain.

3.4 Effect on Infrastructure

Oil and gas activities especially gas flaring has resulted in acid rain which affects buildings and infrastructures. Roofs of buildings in gas flaring communities have been seriously corroded by acid rain caused by gas flaring [102]. Acid rain damages buildings and bridges that have exposed metallic parts to rain and fog. Not only does acid rain greatly dissolve calcium in stones, but it corrodes certain types of metal; vulnerable metals include bronze, copper, nickel, zinc and certain types of steel. A study conducted by some researchers shows that artificial acid rain with a pH of 3.5 can corrode mild steel, galvanized steel, stainless steel and red brass, it was observed that mild steel and stainless steel are the most vulnerable. But other metals were increasingly corroded as stronger acid rains were used [103]. Acid rain when deposited on some materials such as limestone, marble, paint and some plastics used in construction of building cause corrosion. It also causes deterioration of some synthetic materials such as paints and other products used in the building industry.

Pressure depletion resulting from fluid production during oil and gas operations has resulted in land subsidence which can undermine the integrity of structures on the earth's surface. Subsidence can lead to cracks in concrete infrastructure; it can weaken foundations of structures and residential buildings. It

can also generate faults and fractures which affects aesthetics and integrity of physical structures [104-109].

3.5 Other Effects

There are various secondary environmental effects of oil and gas operations and some of them have been extensively discussed especially with regard to the Niger Delta [110, 111]. Oil spill in water bodies and on land can stall economic activities of professional fishermen and farmers [112]. Burying of oil and gas pipelines under the ground limits land use. Deforestation reduces oxygen production from plants and increases the level of carbon dioxide in the atmosphere because the population of plants that absorbs carbon dioxide from the atmosphere has been reduced. Sometimes productive farmlands are lost to oil production operations. During site constructions of oil and gas facilities, large areas of land are disturbed, causing bio-diversity loss which compromises the food chain [113]. During transportation of petroleum products such as diesel or gasoline by land using tankers, accidents though rare sometimes occur on tarred roads. Such accidents sometimes result in explosions and fire outbreaks. When petroleum products spill on roads and prompt measures are not taken to alert drivers, it sometimes results in multiple vehicle accidents especially on rainy days due to reduced frictions between the road surfaces and moving vehicle tires.

4. The Way Forward

Harmful pollutions on environments from oil and gas operations have already occurred in many petroleum producing communities. There is no use crying over spilt milk, the most appropriate focus should be centered on remediation and prevention of future pollution occurrences. Past mistakes need not be repeated; on the contrary, valuable lessons should be learnt from them. There should be a national re-evaluation of the environmental harm that has been inflicted on oil producing communities especially in the Niger Delta region. Thereafter, serious remediation strategies should be implemented and adequate compensations paid to all members of such communities. Modern, well equipped health facilities with free medical care should be provided for such communities and qualified health personnel need to be deployed to such health centers. Good sources of free portable water must be provided as well as free education and scholarship schemes for younger generations. Oil and gas companies and the government should endeavor to put smiles on the faces of every member of an oil and gas producing community to compensate for the past years of suffering.

Proactive measures should be put on ground to prevent and minimize future occurrences of environmental pollution from oil and gas producing companies [114, 115]. Gas flaring must be halted; very prompt cleanup exercises must be conducted in the case of accidental oil spills and explosions.

Petroleum companies should endeavor to monitor pipelines against sabotage and change rusted, damaged and expired pipelines. Produced formation water should be re-injected back into the same reservoir formation from which it is produced. Reservoir formation fines and sand production need be controlled to the barest minimum. Alternatives to seismic survey techniques that are more environmentally friendly should be deployed. Drill cuttings, used drilling fluids, chemicals, refinery effluents and waste discharges must be appropriately treated before disposal or they can be put to other uses. If any petroleum production activity jeopardizes the safety of an environment, then it should not be done, it should rather be abandoned. It is not morally right to compromise environmental safety for financial benefits, if it is not safe, do not do it.

Conclusions

The conclusions drawn from this study are as follows:

1. Environmental pollution is associated with oil and gas exploration and production operations in the upstream, midstream and downstream sectors of the petroleum industry.
2. The major sources of environmental pollution from oil and gas operations are seismic survey, drilling, gas flaring, accidental oil spills and explosions, produced water, produced formation fines and sand, drill cutting, drilling fluids, effluents and waste discharges from refineries.
3. Every component of the environment in a petroleum producing community is affected directly or indirectly by pollution that emanates from oil and gas activities.
4. Oil spillage and gas flaring seem to have the most destructive effects on the environment.
5. Environmental pollution from oil and gas activities has profound effects on human health, the ecosystem, climate, infrastructure, social and economic lives of rural oil and gas producing community dwellers.
6. Strategic plans should be put on ground in Africa to alleviate the sufferings imposed on host community dwellers by exploitation of the oil and gas resources domiciled in their environment. The focus should be on remediation, compensations and strategic preventive measures in view of future pollution.

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