



Review Article

A Review of Impacts of Gas Flaring on Vegetation and Water Resources in the Niger Delta Region of Nigeria

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Abstract: Nigeria is an oil and gas producing nation. The Niger Delta is the Nigerian oil and gas province. About 10 – 40% of produced associated gas is underutilized and is flared into the environment. This is the usual trend in the Nigerian oil and gas industry. Gas flaring has adverse impacts on the environmental components and its associated biota. This paper reviews the impacts of gas flaring on the vegetation and water quality resources in the Niger Delta region of Nigeria. The study found that gas flaring alters water ions (especially sulphate, carbonate, nitrate), pH, conductivity heavy metals (such as lead and iron) concentration especially in rainwater. It also affects vegetation leading to decrease in growth and productivity probably due to changes in soil quality parameters. The paper concludes by suggesting promulgation/implementation of gas glaring laws in Nigeria.

Keywords: Gas Flaring, Impacts, Vegetation Structure, Water Quality

1. Introduction

Following the discovery of crude oil in commercial quantity in Nigeria, the mainstay of the nation economy shifted from agriculture to crude oil and natural gas. Till date, crude oil and natural gas accounts for significant source of revenue and foreign earning to the economy [1]. According to Ohimain [2, 3], Izah and Ohimain [4], about 85% and 90% of Nigerian earning and export respectively are provided by petroleum. Furthermore over 80% of money used in financing national budget is from oil rich region of Nigeria [5]. Nigeria also have other resources including mineral resources such as natural gas, tin, iron ore, coal, lead, zinc limestone, niobium and arable land for agricultural purposes [6]. The country has several other renewable energy resources such as biomass, solar, wind, hydropower etc [4].

Crude oil and natural gas account for about 50% of global energy resources [7]. On global perspective, Nigeria is ranked 7th and 12th largest exporters and producers crude oil respectively [8]. It has been reported that Nigeria crude oil and natural gas resources include 35 – 36.22 billion barrel of crude

oil, 187 trillion standard cubic feet barrel of natural gas and 31 billion barrel of oil equivalent of tar sand [2, 3, 9, 10].

Nigeria have been reported to produce about 6 billion standard cubic feet of gas per daily [10] and 2.2 – 2.7 million of crude oil daily [3, 10, 11]. But the production rate varies due to several factors such as the activities of militants in the oil rich region of Nigeria, pipeline vandalism, sabotages, oil spills, among other factors. Of these, the activities of militia in the region have significantly affected the production rate in Nigeria. For instance, crude oil production significantly decreased in first half of 2016 due to activities of militancy and resource control.

The Nigeria crude oil and natural gas is domicile in the Niger Delta including Ondo, Edo, Delta, Bayelsa, Rivers, Abia, Imo, Akwa Ibom and Cross Rivers states. The crude oil and natural gas is located in both offshore and onshore in the region. Two major products are produced include crude oil and natural gas. Both have adverse effect on the environment. Crude oil could spill into the environment and change the characteristics of the receiving environment including soil [12 – 14] and water quality. In some cases, the volatile

components of the crude oil are released into the air. The natural gas are basically utilized while the excess in flared into the atmosphere through combustion processes.

Gas flaring is common in the Niger Delta region of Nigeria. During flaring several pollutants gases are released into the environment including nitrogen dioxides, sulphur dioxide, volatile organic compounds like benzene, toluene, xylene, polyaromatic hydrocarbons, hydrogen sulfide, benzopyrene and dioxins [15, 16], and particulates.

As such, several impacts (including human and environmental) are associated to gas flaring. Several studies have indicates the impacts of gas flaring in the Niger Delta including vegetation and physical infrastructure such as roofing sheet, buildings/structures, artifacts, monuments, paints [15, 17 – 23], pathological and psychological impacts on human health [24]. As such, several diseases have been reported to be associated with gas flaring including excessive heat and discomfort [18], gastrointestinal problems, skin diseases, cancer, neurological, reproductive and developmental effects, haematological and respiratory ailments [15], heart (cardiovascular) related illness including atherosclerosis, hypertension and ischaemic heart disease [25, 26], renal and related diseases [27], bronchitis, asthma, cancers and several other diseases [20]. Most of the impacts are due to indirect effects resulting from acid rain. These could also affect other biodiversity resources including humans. For instance, acid rain which could result from gas flaring has the tendency to cause lung related diseases, and affect aquatic organisms such as fishes and other wildlife and natural forest resources such as vegetation. Furthermore, Noise emanating from the flare could also affect humans residing close/ and or working close to the vicinity.

As such the exploration of oil and gas and flaring of natural gas has several environmental impacts. Therefore, this study reviews the impacts gas flaring on groundwater resources and vegetation structure and cover in the Niger

Delta region of Nigeria. The paper is organized into 5 sections. Section 1 is the introduction providing information on oil and gas resources in Nigeria and overview of the impacts of gas flaring in the Niger Delta. Section 2 discussed gas flaring in Nigeria. Section 3 discussed the effect of season and distance of disposal of emission. Section 4 discussed the impact of gas flaring to vegetation and water resources. Section 5 is conclusion and the way forward.

2. Gas Flaring: A Nigerian Scenario

Globally, high amount of gas is flared in to the environment by oil and gas producing countries. Nigeria being among the world producing nations, flare a significant amount of natural gases into the environment through vertical and horizontal flaring stack (Figure 1). Globally about 110 billion cubic meters of associated gas is flared per annum [28]. Ogbe [29] opined that Nigeria account for about 12.5% global flared gases per annum [29]. The flaring of gases is a global issue for some decades now [3]. Emam [31] described gas flaring as the used combustion device (flare stack) to remove unwanted gases and liquids during operation in many industrial processes, such as oil-gas extraction, refineries, chemical plants, coal industry and landfills to prevent unplanned over-pressuring. Soltanieh *et al.* [32] also noted that gas is flared in producing nations due to a number of reasons such as inadequate infrastructure to collect, treat, transport and utilize the associated gases; location of the production site is remote from the market demand (such as offshore sites); small volume of the gas and its fluctuation, which make the design of facilities more uncertain and therefore uneconomical investment; Impurities in the gas that require hard and expensive treatment methods (such as highly acidic gases); safety and operational reasons. Gas flaring leads to release of three major components including noxious gases, heat and noise.

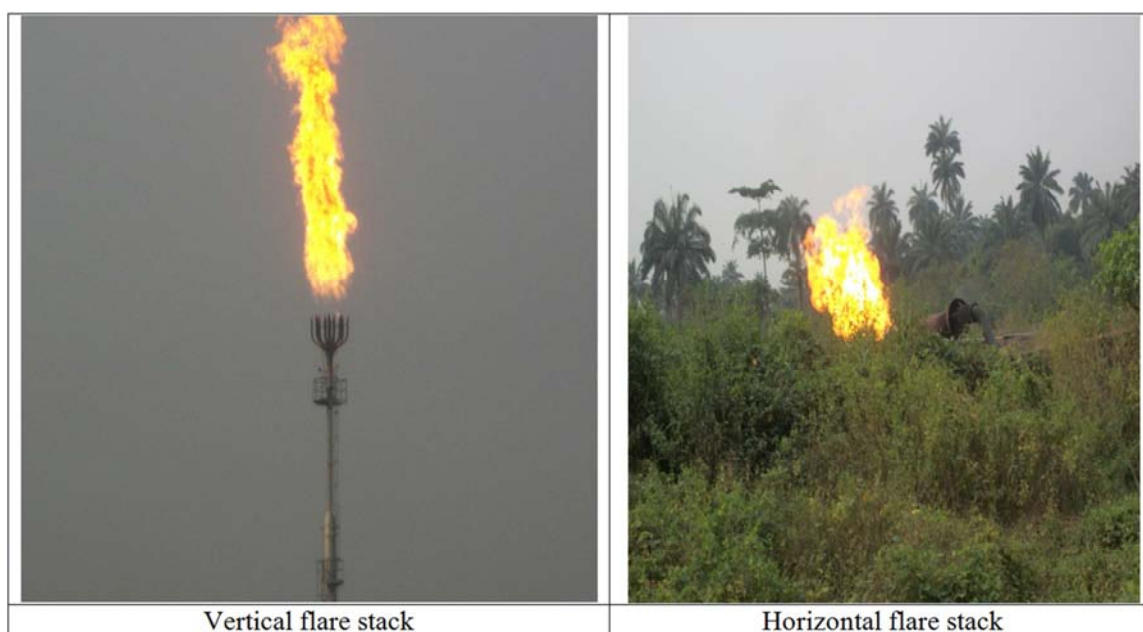


Figure 1. Gas flaring in a location in the Niger Delta.

Natural gas can be converted into different form for downstream applications including electricity generation and cooking gas. But due to inadequate resources for its conversation and utilization, oil and gas companies prefers to flare the gases and pay compensation. According to Donwa *et al.* [15], wastage of gases through flaring is carried out due to problems associated to processing, storing and transporting it in Nigeria setting.

Nigeria flare significant amount of natural gas into the environment leading to loss of substantial amount of money per annum. For instance, World Bank reported that 150 to 170 billion m³ of gases are flared annually, worth up to about \$ 30.6 billion, the price equivalent of one-quarter of the United States' gas consumption or 30% of the European Union's yearly gas consumption [31]. Lower amount of gas equivalent have been reported to loss due to gas flaring to the tune of \$2.0 billion per annum [29], \$2.5 billion [15, 33].

Despite the incentives to capture the associated gas and

bring it to market, the volume of gas flared is still high. About 70million /m³ of natural gas are flared per day [34]. On yearly basis, Donwa *et al.* [15], Ishisone [35] reported that Nigeria flare about 17.2 billion m³ of natural gas in the Niger Delta. Between 2006 to 2014 several oil wells were explored in Nigeria. Table 1 presents information the details of crude oil and condensate production, total gas and quantity utilized and flared between 2006 to 2014. Within the period the production, utilization and quantity flared varies. Also, the amount targeted could not be met. This is typically attributed to several reasons including delays in upgrade of facilities to floodly terrain, inadequate line, limited facilities, obsolete equipment, community disturbance, activities of militia etc. The demand for gas increase as a result of new opportunities for gas micro power, combined cycle turbines, independent power plant, gas to liquids and expansion in liquefied natural gas trade also contributed to the utilization.

Table 1. Crude oil and gas production and utilization in Nigeria between 2004 to 2014.

Years	crude oil and condensate production, barrels		Total gas, Billion Standard Cubic Feet	Quantity of gas utilized, BSCF	Quantity flared, BSCF	References
	Total	Daily average, mmb/pd				
2014	798,541,589	2.19	2,524.27	2,233.49	289.60	[36]
2013	800,488,102	2.19	2,325.14	1,916.53	409.31	[37]
2012	852,776,653	2.27	2,580.17	1,991.50	588.67	[38]
2011	866,245,232	2.37	2,400.40	1,781.37	619.03	[39]
2010	896,043,406	2.45	2,392.84	1,811.27	581.57	[40]
2009	780,347,940	2.14	1,837.28	1,327.93	509.35	[41]
2008	768,745,932	2.10	2,282.44	1,664.97	617.62	[42]
2007	803,000,708	2.20	2,415.65	1,626.10	789.55	[43]
2006	869,196,506	2.38	2,182.43	1,382.43	799.99	[44]

Furthermore, Nigeria flares about 11 – 42.54% of total natural gas produced. These make Nigeria one of the largest gas flaring nations in the World. Several oil wells are built with the period of 2004 to 2014, with an average of 155 per annum. According to Oniemola and Sanusi [45], Nigeria has about 160 oil fields having about 1500 oil wells that produces 2.2 to 2.7 million barrels/day. The authors reported that of these, 17 billion m³ of associated gas are flared leading to the releasing 2,700, 160, 5400, 12million and 3.5 million tons of particulate, sulphur oxides, carbon monoxide, carbon dioxide and methane respectively. The number of wells has far increased due to continual exploration.

3. Effect of Season and Distance of Disposal of Emission

Nigeria has two predominant season including wet season (April to October) and dry season (November to March of the following year). The rainfall pattern is usually optimum in June, July and September. The effect of meteorology especially temperature, rainfall, relative humidity, wind speed have been reported in the Niger Delta specifically in Bayelsa state [46].

Season affects the rate of dispersal of pollutants and noise. Dispersal of pollutants resulting from emissions is affected by

season. For example, Anomohanran [18] reported pollution from thermal plant within a distance of 2.15 km and 2.06km in wet and dry season respectively. Several metrological parameters affects dispersal rate of pollutant gases. Some of the notable once include wind speed, wind direction, closeness to ocean.

Distance in another major factor that could affect the emission of pollutants. Emission rate typically decreases as distance from the source of pollution is increased. Ojeh [47] reported that in a gas flaring station, the concentration of noxious gases reduces as the distance increased in gas flaring site. But the effects of gas flared could be felt within 450m radius of the flare stack which could be depend on the volume of gas flared, wind speed, temperature, temperature, velocity of discharged and height of the stack [47]. In non-gas flaring site, specifically on oil palm processing mill, emissions also decreases as the distance from the sources increased [48, 49]. Though, instances of fluctuation in wind speed and direction during measurement could lead to shorter distance from emission source having lower values instead of higher values compared to long distance.

4. Impacts of Gas Flaring on Water Quality and Vegetation Resources

Gas flaring typically has two valves, the high and low gas

pressure valves. Hence, the concentration of emissions, noise, released is a function of the valve used in flaring the gas as well as the physical composition of the gas prior to flaring. The flared gases affect several environmental components as well as its biotic composition. The section of the paper affects the impact of gas flaring on water quality and vegetation resources.

4.1. Changes in Water Quality

Water resources are typically needed for the sustenance of life, growth and development [50 – 62]. Water serve as habitat to several biodiversity especially fisheries (shelled and finfish), aquatic reptiles, mammals, birds and breeding ground for several other diversity such as frog, parasite of medical importance such as Schistome, and vectors transmitting diseases such as mosquitoes. As such water has a unique place for life to thrive.

Water is also used for domestic purposes such as washing, cooking, bathing [63]. Most water resources are from surface water, groundwater and rainwater [52]. Izah et al. [50] is with the opinion that groundwater is mostly consumed in the Niger Delta and surface water and rainwater also serve as potable water sources in regions that groundwater/ borehole water is unavailable.

Water is typically impacted by gas flaring activities. Authors have variously reported that some water quality parameters of surface water, ground water and rain water are affected in gas flaring locations in the Niger Delta. For instance, Dami et al. [64] studied the impacts gas flaring and oil spillage on rainwater quality for domestic use in Okpai and Beneku areas of Delta State and reported that temperature, taste, color, conductivity, total dissolved, salts and alkalinity were altered when compared to the permissible limits specified by National Agency for Food and Drug Administration and Control, United State Environmental Protection Agency and World Health Organization for drinking water. Dami et al. [65] studied the impacts of gas flaring and oil spillage on groundwater quality for domestic use in Okpai and Beneku areas of Delta State and reported that color is majorly impacted and to lesser extent conductivity were affected in some locations due to accumulation of dissolved salts and other organic materials when compared to World Health Organization standard. Nwankwo and Ogagarue [66] studied the effect of gas flaring in surface and groundwater quality in Delta state and reported that water from gas flaring area contain higher concentrations of metals such as barium, cyanide, selenium, cadmium, chromium, iron, manganese and copper, conductivity, color and taste when compared to non-flaring location. Emumejaye [67] studied the effects of gas flaring on surface and ground water in Irri town and environs and reported that high content of iron and lead in the water which the author attributed to gas flaring in the area. Ezenwaji et al. [68] studied the effects of gas flaring on rainwater quality in Bayelsa State and reported that all the parameters studied including temperature, lead, conductivity, total dissolved solid, nitrate, carbonate, sulphate and pH had values above World Health Organization permissible limits.

The authors further reported that nitrate contributing the highest of 38.44% to poor quality of rain water in the area. Amadi [17] reported that concentration of the major anions (bicarbonate, sulphate and nitrate), temperature, conductivity, heavy metal content and total hydrocarbon content increase significantly in the vicinity of the gas flaring location and steadily declined in surface water, groundwater and rainwater away from the flaring location. Efe [69] studied the effect of acid rain and reported that pH values (which is usually used to measure the acidity of the water) were lower (4.96) in the Niger Delta compared to coastal region of the Northern Nigeria with a mean pH of 5.36 which indicate the impact of acid rain. Other effects of acid rain on water quality have been comprehensively documented in literature by Ogunkoya and Efi [70], Ubani and Onyejekwe [23], Olobaniyi et al. [71], Efe and Mogborukor [72].

Among the water quality parameters commonly affected by gas flaring is nitrate, carbonate, sulphate, nitrate, lead etc. Amadi [17] reported that gas flaring reduces pH (pH tending toward acidity), moisture content and bacteria density/population. The intensity of the flare with regards to microbial density in water is usually higher in horizontal flare compared to the vertical flare stack. The heat from the flare could enhance the temperature of the environment including water. High occurrence of sulphate and nitrate ions may be connected to the emission of carbon, sulphur and nitrogen oxide during flaring activities. The occurrence of ions in the water could lead to high conductivity level in water close to gas flaring location.

4.2. Impact on the Vegetation

Plants are a major source of active nutrients required by the body. Plants are source of carbohydrate, protein, lipid and other minerals and vitamins depending on species. Vegetation is also source of food for livestock especially omnivorous animals such as goat, cow, grass cutter, rabbits etc. Vegetation cover is also a source of habitat to several wildlife species especially bushmeat that do not burrow. Some notable vegetation is found in close to farmland and residential area such as cassava and oil palm. These are two predominant vegetation cover used as food found close to gas flaring location in the Niger Delta. Gas flaring has the tendency to affect several plant species [73] especially productivity and growth [74]. For instance, Lawanson [75] reported that gas flaring decreases the length and weight of cassava and increase its amino acid and total sugar contents as the distance from the flares decreases. The authors furthered reported that such decreases were also correlated with decreases in the content of starch and ascorbic acid (vitamin C) in the tubers. Based on survey study in the Niger Delta region, 77% of the resident is with the opinion that gas flaring affect vegetation and agricultural activities [76]. In a similar study the resident of Ebedei community in Delta state 94.6, 90, 98.75, 50.4 and 5% is with the opinion that gas flaring affect food such as yam, cassava, okra, plantain and potatoes [74].

Gas flaring can also cause deforestation and acid rain [74]. According to Ezenwaji et al. [68], exploitation of crude oil and

associated gas flaring is a major contributor of acid rain in the Niger Delta region of Nigeria has had a fairly long history [68]. Acid rain could lead to loss of vegetation [17] and several symptoms in plants that could lead to their death. Some of the notable symptoms include chlorosis, abscission and yellowing of leaves, wilting of the leaf tips and accelerated senescence, root and shoot of plants are also destroyed and microbial community that aid in decompositions processes [69]. The impacts of acid rain on vegetation structures and cover is most severe close to gas flaring stack [69].

Acid rain result in the decline in productivity and growth of some major food crops such as cassava, sweet potatoes, maize, melon, plantain, and cash crop like rubber [69]. The impacts in the growth and productivity of crops could also be an indication that the soil fertility have been impacted upon. This may lead to loss of vital soil nutrients that encourage the growth of plants. Other authors have comprehensively reported the effect acid rain on vegetation have been documented by Jacobson [77], Neufeld et al. [78], Efe [79].

Plants are known to pharmacological and bioactive composition [80, 81]. The composition of the bioactive constitutes play a significant role in determining their medicinal properties. The effect of gas flaring on the nutritional and bioactive component of vegetation established. For instance, Ifemeje [82] reported gas flaring could change the anti-nutrient compositions (alkaloid, phytate, oxalate, Saponin, tannin and cyanogenic glycosides) in some common vegetables used for food purposes such as scent leaf, bitter leaf, water leaf and fluted pumpkin leaf. Ujowundu *et al.* [83] also reported impacts in phytochemical (alkaloid, tannin, cyanogenic glycoside, phytate), proximate composition (moisture, ash, protein and carbohydrate), micronutrients (calcium, sodium, magnesium, potassium and phosphorus) and vitamins (riboflavin, vitamin E and C) in African breadfruit and Bambara groundnuts planted close to gas flaring stack. Anacetius *et al.* [84] also reported that phytochemical (alkaloids, flavonoids, saponins and tannins) and trace metal (iron, lead, cadmium and zinc) constituents of fluted pumpkin could be affected by gas flaring.

Vegetation plays several ecological roles. For instance Izah et al. [85] reported that vegetation prevents soil erosion. Gas flaring is known to cause physical damage to plant close to the flare stack [17]. This could lead to other downstream impacts. In addition, gas flaring could alter soil quality parameters [86] including physiochemical and microbial characteristics. Some notable soil quality parameters such as pH, temperature, soil moisture, soil microbial population are commonly impacted by gas flaring [23]. Okeke and Okpala [86] reported that soil quality parameters from flaring sites such as temperature and bulk density decreased with distance from the flare point while other such as CEC, organic matter, moisture content etc) increases with distance. The authors further asserted that soil nutrient were lower in gas flaring environment compared to the control in Eket and Izombe area of the Niger Delta. Variation in soil characteristics especially the nutrient related characteristics may affect the crop productivity indirectly. Microbes being unique, changes in the soil properties could

alter the microbial diversity and density. Typically microbes play essential role in nutrient and biogeochemical cycling.

In a survey study, the resident of Okpai, Ndokwa East Local Government Area, Delta State is with the opinion that gas flaring is having impact on the soil including its fertility and productivity for food crops such as cassava, plantain, yam [87]. Also maize is also affected by gas flaring and cassava [88, 89].

5. Conclusion and the Way Forward

The Niger Delta region is one of the most productive and fragile ecosystem in Nigeria. The area is rich in vegetation with several pharmacological properties and water resources. These resources are constantly being destroyed by the activities of man in quest for industrialization and urbanization. Several oil and gas installations are found in the region. Gas is used by gas-turbine for electricity generation. Despite the huge source of gas available for electricity, the gas is constantly flared into the environment. While electricity supply remain epileptic in the region. Nearly 10 – 40% of natural gas produced is under-utilized and therefore flared into the environment. Gas flaring are known to have impact on air quality, physical infrastructure, biodiversity composition including plants and animals especially insects, impacts on human health over a prolong period of time and water resources especially rainwater. Acid rain has been widely attributed to impact of gas flaring especially in the Niger Delta region of Nigeria. On water quality, gas flaring alters ions especially sulphate, carbonate, nitrate, pH, conductivity, lead and iron concentration especially in rainwater. On vegetation perspective, it could lead to loss of vegetation cover, reduced growth and productivity/yield probably due to changes in soil quality parameters.

Based on the review, the attendant impacts associated with gas flaring on vegetation and water quality could be reduced through:

- a. utilization of the gas and generation of revenue from it, promulgation of associated gas re-injection and amendment of flaring policy to more reasonable amount [67].
- b. enforcement of laws aimed at minimizing the amount of gas flared into the atmosphere [68].

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