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Review Article

Impact of gas flaring on communities in Delta region of Nigeria, narrative review part 1: environmental health perspective

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ABSTRACT

Gas flaring is the combustion of associated gas from crude-oil exploitation and exploration operations and occurs in refineries, oil wells, oil rigs by fiery of the gas. Nigeria is one of the main producers of gas in the world and oil exploration activities have occasioned high rate of gas flaring because of poor enforcement of anti-gas flaring laws by the regulatory authorities. Gas flaring comes with serious environmental concern because it is a major source of air pollution with adverse public health consequences particularly in the gas flaring communities. The objective of this narrative review is to identify the risks associated with gas flaring in relation to the environment. Literatures from diverse databases including peer reviewed journals as well as governmental and organizational papers were searched to develop the narrative. Over the years, several laws have been enacted in Nigeria with stipulated dates to end gas flaring, but the targets have not been met. The Federal government of Nigeria updated the legal framework titled flare gas (prevention of waste and pollution) regulations, 2018 to facilitate financial profits through utilization and commercialization of associated gas, with a view to reduce or exterminate flaring. This effort appears ineffective due to weak enforcement and poor monitoring mechanism. The statutory government institution entrusted to enforce anti-gas law may benefit from some sort of motivation to ensure oil operators comply to combat environmental health risks from gas flaring.

Keywords: Occurrence, Impact, Risks to human health, Government interventions

INTRODUCTION

The former world bank president, Jim Yong Kim noted that continuous flaring gas is wasteful handling of CO_2 emission and encouraged countries and oil companies to positively respond to this menace and noted that the world can collectively take concrete action to end flaring and use this valuable natural resource to light where there is no electricity.[1]

As mentioned, gas flaring is primarily the burning of gas associated with oil production and it is usually carried out in places where there are insufficient infrastructures to handle the gas.[2] This practice has drawn global attention for years and policy makers have brainstormed to reduce or end routine flaring.[3] reported that flaring gas was responsible for several health and environmental challenges and some negative impacts of gas flaring include global warming, climate change, environmental pollution, loss of livestock and respiratory challenges. Nigeria has the ninth largest gas reserve in the world with a reserve of 199 trillion cubic feet (TCF). A significant volume of gas produced with crude oil is flared and Nigeria is the seventh highest gas flaring nation in the world, with daily flare of about 800 million standard cubic feet (DPR, 2019).[4] Reports show that communities close to oil and gas exploratory activities suffer from harmful effects associated with gas emissions.[5] Apart

from pollution, there is the hazard of oil spill, as well as health challenges in communities close to gas flare. It is sad to see that the oil companies focusing mainly on oil and neglecting the potential of harnessing gas as an energy source and also not focusing on the negative effects of burning the gas.

According to information from the United States, 1 million standard cubic feet of gas can generate 1.036 billion british thermal unit (BTU) of energy and harnessing this energy can alleviate the huge energy generation deficit in Nigeria.[6] In 2017, the president of Nigeria, Muhammadu Buhari, accented to the passage of the Paris climate accord, which tasked nations to reduce greenhouse gas emissions unconditionally by 20% and conditionally by 45%. The Paris agreement is expected to deliver 100 billion US dollars per year by 2020 in support of developing countries, to implement this.[7] It must be pointed out that curbing gas flaring goes beyond signing accords, proactive steps are needed from relevant stakeholders such as governments, and oil and gas companies to reduce and ultimately stop gas flaring. A review of fees and fines imposed for flaring of gas in Nigeria shows that the fees are low that it is cost-effective to pay the fine than invest in harnessing the produced gas. This is a disincentive for oil and gas producers whose focus is to extract oil at little cost.[5]

This paper narrates in sequence of four sections to explain the phenomenon (occurrence) of gas flaring, the impact of gas flaring in Nigerian communities, risks associated with gas flaring in relation to human health and community health studies and the government interventions. This narrative review is a first step in the continuation and expounding of a preliminary work previously published.[8]

PHENOMENON OF GAS FLARING

Natural gas is a naturally occurring hydrocarbon mixture, which consists primarily of methane and varying amounts of other higher alkanes such as ethane, propane, as well as butane, and a small percentage of carbon dioxide, nitrogen, and/or hydrogen sulphide can also be found. Natural gas is produced when layers of putrefying plant and animal matter are exposed to intense heat and pressure over thousands of years. It is a fossil fuel used as a source of energy for cooking, heating and electricity as well as fuel for vehicles and in the manufacturing of plastics and other organic chemicals. Natural gas can be found in oil and natural gas fields, and in coal beds as coalbed methane.[3]

When petroleum exploration commenced, natural gas was not considered useful because of the difficulties in transporting to markets and its storage. As a result, the gas was burned at the well or vented into the atmosphere, to create room for other operations and to avoid gas explosion.[3] Presently, flaring and venting is ongoing in locations where local markets and gas transportation infrastructures are not available, or where the gas is contaminated with other incombustible gases.

There are multiple definitions of gas flaring and these include: process of burning-off the gas found mixed with crude oil (popularly called associated gas) during the extraction of crude. This occurs because it is costly to separate associated gas from the oil. Some oil companies burn the gas directly from pits while others construct flare stacks. The flares often contain as many as 250 different toxins, and emit particulate matter, mostly sulphur dioxide and nitrogen oxides, as well as, carbon dioxide, formaldehyde, radon, lead, ammonia, and methane. Also contained in the flares are carcinogenic substances and unburned fuel components such as benzene, toluene, xylene, and hydrogen sulphide.[9] Ignition devices to securely and ably extinguish waste gases produced in a plant during normal operation. Waste gases come from diverse sources such as associated gas, gas plants, well-tests and other places and are collected in piping headers and delivered to a flare system for safe disposal.[10] Burning of natural gas associated with oil extraction and takes place because of technical, regulatory, and/or economic constraints. This causes more than 350 million tons of CO_2 emissions every year, with serious harmful impacts from methane that has not been combusted and black carbon emissions. Gas flaring is also a substantial waste of energy resources the world can ill afford.[11] Steady discharge of gaseous fuel into the atmosphere during petroleum exploration activities.[12] Gas flares burn to a height equivalent to several storeys throughout the Niger Delta, often near communities. Some flares, such as shown in (Figure 1), have been burning constantly day and night for over 30 years.[13] In 2002, the world bank estimated that globally, about 108 billion cubic meters (bcm) of natural gas was flared and vented annually and such an amount was equivalent to the combined annual natural gas consumption of France and Germany. It also noted that gas flared in Africa (37 bcm in 2000) produced 200 terawatt hours (TWh), which was about 50% of the power consumption of the African continent, and more than twice the level of power consumption in Sub-Saharan Africa (excluding the republic of South Africa.[14]

Figure 1: Picture of a gas flare site.[13]

The world bank also reports that billions of cubic meters of natural gas are flared annually at oil production sites around the globe.[11] Flaring gas wastes valuable energy that can be used for economic growth and it also contributes to climate change by releasing millions of tons of CO_2 into the atmosphere.

The top 30 gas flaring countries in the world are shown in (Figure 2). Nigeria, Africa's biggest gas energy producer was second highest in 2011 and dropped to sixth between 2013 and 2017 as reported by the U.S. National oceanic and atmospheric administration (NOAA) and global gas flaring reduction partnership.[4] An average of about 130 billion cubic metres (bcm) of gas are flared in the world yearly, and Nigeria contributes substantially.[15,16] A high proportion of natural gas extracted in oil wells in Niger Delta is immediately flared into the environment at approximately 70 million/m^3 per day and this is equivalent to 40% of African natural gas consumption and is the largest source of greenhouse gas emission on the planet.[17]

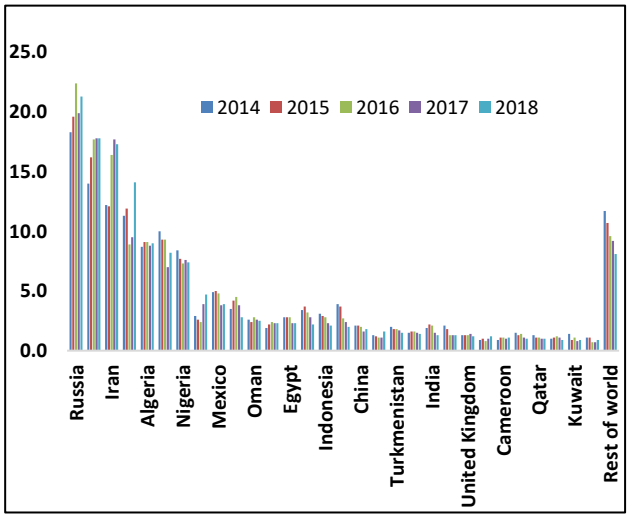

Figure 2: The ranking of top 30 gas flaring countries (2013-2017).[4]

It has been observed that gas flaring was dangerous and an abuse of human rights because the gas pollutants contain over 250 different toxins that are harmful, poisonous and unfriendly to the ecosystem and humans.[18] Constituents of a gas that is flared are diverse and depend on the source of the gas and the magnitude of released hydrocarbons are related to the rate of ignition.[19]

The gas can be processed and used for fuel rather than flared. In the United States, oil companies process and use natural gas or re-inject gas into the ground, and only about 1% of gas is flared while in Nigeria, as much as 60% of associated gas is wasted in flare but only 40% of people have access to electricity. There is therefore a need for flared gas to be processed, distributed, and used e.g. as fuel for cooking or for electricity. Using processed natural gas as fuel for cooking can replace firewood that Nigerians use for cooking and improve air quality. Gas can also be re-injected into the ground, a clean option that keeps the gas from being burned and creating greenhouse gases.[13] A marked reduction in the percentage of gas flared from 2000 to 2017 in Nigeria is shown in (Table 1). Although the proportion of gas flare is down, it is still a considerable waste and constitutes physical, environmental and health hazard. In addition, there is a general consensus that gas flaring is wasteful and unnecessary, it has harmful impact and contributes to global warming and climate change by releasing millions of tons of CO_2 to the atmosphere.[5,18,21,22]

Table 1: Gas produced in Nigeria, the quantity flared and the percentage flared.[20]

Year	Gas produced (BCF)	Gas flared (BCF)	Percentage flared (BCF)
2000	1,720.81	929.97	54
2001	1,943.60	1,000.75	51
2002	1,751.13	920.93	53
2003	1,903.33	801.47	42
2004	2,110.18	851.65	40
2005	2,135.34	805.52	38
2006	2,289.89	820.43	36
2007	2,606.87	816.64	31
2008	2,580.40	670.79	26
2009	2,228.12	536.37	24
2010	2,819.68	544.73	19
2011	2,966.65	503.94	17
2012	2,996.04	465.26	16
2013	2,811.98	427.97	15
2014	3,048.55	379.17	12
2015	3,004.55	341.35	11
2016	2,711.80	288.88	11
2017	2,938.05	324.30	11

IMPACT OF GAS FLARING IN NIGERIAN COMMUNITIES

Gas flaring commenced in Nigeria during the discovery and production of oil and gas in 1956. A study on the level of ambient air pollutants in the Niger Delta region relative to Lagos state revealed that pollutants levels are uppermost in the former where the majority of flare sites are.[23] The author maintains that some of the greenhouse gases emitted at flare sites contribute to global warming. The oil rich Niger Delta of Nigeria lies between 4° and 6°N of the equator and between longitude 5^0 and 9^0E of Greenwich, with an estimated area of 70 000 Km^2. The Niger Delta consists of a number of distinct ecological zones, characteristic of large river deltas in tropical regions, coastal ridge barriers, mangroves, freshwater swamp forests and lowland rain forests. The major consequences of gas flaring are severe environmental damages, loss of plants and animal lives, loss of revenue to Government and damage to health of the

communities.[5] Furthermore, gas flaring in the Niger Delta has resulted in thermal radiation, flue gas dispersion and emissions from flare systems and these have produced considerable amounts of air pollutants over the past 50 years. Flaring and venting of associated gas in Niger Delta contributes approximately 35 million metric tons of carbon dioxide (CO_2) per year, methane (CH_4), a large number of hydrocarbons and other forms of greenhouse gases (GHG) into the atmosphere. For example, methane constitutes approximately 86% of the natural gas, and because of the low burning efficiency of the flares, a big percentage of the associated gas released is methane that has a higher global warming potential.[24]

Gas flaring has made communities poor and there is increased mortality rate, with attendant environmental, economic and health difficulties and these difficulties are sufficient justifications for ending gas flaring.[5] Gas flaring contaminates water and food and causes ill-health, environmental degradation and displacement of people from their ancestral homes.[22] According to world bank (2002), gas flaring in Nigeria contributed more greenhouse gases to the earth's atmosphere than the combined contribution in the Sub-Saharan Africa. Further, gas flaring impacts negatively on terrestrial ecosystems with particular emphasis on plant growth and development.[25] Gas flaring emits air pollutants such as oxides of nitrogen, carbon and sulphur.[5] These pollutants increase the acidity of the soil thereby making no flora thrive in the area surrounding the flare, destroys mangrove swamps and salt marshes, reduces growth of some plants and causes soil degradation and declines agricultural productivity.[25,26] In some cases, there is no vegetation in the areas surrounding the flare due partly to the heat produced and acid nature of soil. In the same vein, study on the effects of gas flaring on crop farming in the Niger Delta showed that crops' growth are retarded.[27]

RISKS ASSOCIATED WITH GAS FLARING IN RELATION TO HUMAN HEALTH

As mentioned, gas flaring, which is routinely carried out by oil exploration companies poses a significant hazard to the health of populations since it pollutes the air, heats the atmosphere and releases GHG.[28] Although Nigeria pledged to stop gas-flaring and imposed fines on oil exploration, companies still flare gas. The health of the people in the Niger-Delta is therefore compromised and the people may not be educated enough to know the extent. They live and work alongside the flares with no protection. While there is a substantial public concern about the environmental impacts, consequences and damage of gas flaring in the Niger Delta, the magnitude of pathological and psychological effects in the local communities are slightly known.[29] Indeed, most studies in various parts of the world have included monitoring air pollution levels and the health impacts.[30] However, similar large-scale comprehensive studies on the impact of air pollution on health have not been conducted in the Niger Delta. Few short-term studies have however been carried out in the Niger Delta. In the next section, the indirect and direct risks associated with gas flaring are discussed.

Indirect risks associated with gas flaring in relation to human health

It is reported that Nigerian gas flares release about 18 million metric tons of greenhouse gases and discharge lethal substances in the environment.[31] Gas flaring causes global climate change and greenhouse-effect resulting in gradual rise in atmospheric temperature and depletion of the ozone layer, the natural cooling shield from sun rays insulation and heat in the sky, thereby exposing the earth to high intensity of solar radiation. The impact of the environmental threat includes food insecurity, increasing risk of disease, acid rain, rain corrosion of buildings and the rising costs of extreme weather damage because of toxins such as benzene in the air.[18,32] Due to global warming caused by emission of greenhouse gases in the atmosphere during human activities such as during gas flaring, depletion of stratospheric ozone layer occurs that leads to increase in the solar UV-B radiation (280-315 mm) at the surface of the earth. The harmful effects of UV radiation include cataracts in the eyes, permanent or temporary blindness, skin cancers, DNA damages, lung diseases, suppression of immune responses to skin cancer, infectious diseases.[33]

Furthermore, studies reveal that gas flaring creates noise pollution and flaring at elevated temperature results in discharge of soot and particulate. Exposure to noise pollution is associated with a variety of ill-health including but limited to hypertension, cardiovascular disease, stress, hearing loss, reduced reproduction, sleep disturbances, among others.[34-36] Flares coat the land and community with soot and damage vegetation and they heat and change in soil pH.[37-39] A negative impact of gas flaring is also the potential to destroy the medicinal plants that rural and urban people use. Uncontrollable gas flaring produces soot laden with toxic substances including hydrocarbons, sulphur oxides and the oxides of nitrogen, which negatively affect soil fertility as mentioned and are linked to ailments such as bronchial, chest, rheumatic and eye problems. In the same vein, soot is associated with difficulty in breathing, lung, and throat irritation, birth related problems, such as low birth weight; and, heart disease.[40]

Gas flaring in the Niger Delta is reported to cause acid rain and people in Nigeria rely on rainfall for laundry, cookery, drinking (humans and animals) and other domestic purposes. Consumption of acid rain is associated with skin cancers, lesions and stomach ulcers and leaching the mucous membrane of the intestinal walls.[41] In addition, many communities in the Niger Delta believe that acid rain due to local gas flares corrodes roofing especially zinc roofing. This view is supported by report that acid rain from gas flaring increased the

corrosion of zinc roofs in the Niger Delta.[42] Such findings have encouraged the use of asbestos roofing.[37] Since asbestos has better repelling properties to acid rain. Having said that, asbestos increases the incidences of diseases such as cancer of the lungs, pleural and peritoneal mesothelioma, as well as asbestosis.[43] There are different schools of thoughts concerning the relationship between gas flaring and acid rain with some noting that gas flaring contributes to acid rain. Reports point out that the levels of sulphur dioxide and nitrous oxide emitted from most flares are sufficient to produce acid rain.[5,37,38,42,44]

Table 2: Table showing Government intervention to end gas flaring in Nigeria.[20,56,57]

Year	Government intervention
1958	Oil production commenced and all gas produced was flared at this time
1969	The petroleum act was enacted and the petroleum drilling and production act provided for operators to submit their gas utilization plan.
1979	The associated gas re-injected act was enacted, to encourage the reinjection rather than flaring of gas. Flare deadline was set at 1984
1985	The associated gas re-injection regulation was enacted, prescribing fees for flaring.
2010	The gas flaring prohibition bill was developed however it is didn't receive legislative attention. This bill proposed a flare fee of $3.50/1000scf flaring penalty
2006, 2007, 2008	Other gas utilization programmes include: National gas master plan in 2006 which was swiftly followed by a national domestic gas supply and pricing policy 2007 and the National gas supply and pricing regulation in 2008, which were aimed to fully align the gas sector with the economic growth aspiration of the nation
2016	The National gas flare commmercialization program. Launched in 2016 to invite 3rd party investors to take and utilize gas at flare
2018	The federal Government recently signed the flare gas (prevention of waste and pollution) regulations 2018, specifying new penalties for gas flaring in the country
2020	Proposed gas flare deadline is the year 2020

Direct risks associated with gas flaring in relation to human health

Literature has highlighted risks associated with gas flaring in relation to human health but there is no comprehensive study done on the health impact of gas flaring on humans. Flaring of gas in Niger Delta releases contaminants that affect air quality negatively thereby increasing health risks such as tumours, neurological, reproductive and developmental disorders.[24,40] As mentioned, gas flaring discharges toxic compounds into the atmosphere and these cause damage to skin cells, different types of cancers, asthma, blood disorders, leukemia, bronchitis, respiratory problems and anemia in the communities in proximity to the flaring. The discharges consist of toxic compounds and elements, such as benzene and enter the food chain and cause health disorders. Adverse health conditions substantially reduce life expectancy.[37,45-47] Data from several studies suggest that impurities and toxic particles due to flares, cause harmful effects on human health and ecosystems. The human health effects of gas flare pollutants in the Niger Delta are shown in (Table 3).

Table 3: Human health effects of gas flare pollutants in the Niger Delta.

Chemical name	Human health effects
Ozone in land	Can cause respiratory problems and eye defects.[48]
Alkenes, thylene, propylene	Could result in weakness, nausea and vomiting.[48]
Hydrogen sulphide	Headaches, nausea, delirium, tremors, convulsions, skin and eye irritation, respiratory tract and mucous membrane irritation, may cause immediate or delayed pulmonary edema, may result in extremely rapid unconsciousness and death.[48,49]
Carbon monoxide	Can cause permanent damage to the heart and brain, may harm the mental development of fetus and children and can lead to miscarriage and death.[48,50]
Nitrogen dioxides (NO, NO_2)	Cause irritation of eyes, nose, throat, and lungs. Cough, shortness of breath, tiredness, and nausea may also occur. Build-up of fluid in the lungs 1 or 2 day(s) after exposure is also possible. May result in rapid burning, spasms, and swelling of the upper respiratory tract and throat tissues. Reduced oxygenation of body tissues, a build-up of fluid in lungs. It may lead to death.[51,52]
Alkanes: methane, ethane, propane	Cause swelling, itching, inflammation, skin infection such as eczema, acute lung swelling.[48,53]
Aromatics: benzene, toluene, ethylene, and xylene	It is toxic, poisonous and carcinogenic, causes blood abnormalities, causes depression and affects nerve system negatively.[48]

Research shows that exposure to these pollutants from flared gas can lead to severe health risks especially persons who reside and engage in work close to the flaring sites within the host communities.[54]

Unfortunately, most gas flaring sites in the Niger Delta are situated close to the residences of the inhabitants.[55] reported of an association in residents of Igwuruta/Umuechem communities that have a long history of gas flaring, with frequency of health conditions such as cough, eye and skin irritation, as well as asthma compared to Ayama community with no gas flaring. In view of the foregoing, threat to human health posed by pollution due to gas flaring cannot be ignored and there may be extensive human health effects associated with oil pollution in the Niger Delta.

Government intervention to end gas flaring in Nigeria

The federal Government of Nigeria is concerned with the growing trend of gas flaring and has several measures to curb this and some are shown in (Table 2). Although these measures have reduced the amount of gas flared in respect of the volume of gas produced, a lot needs doing to further reduce the volume. In 2017, 324 BCF of gas was flared in the country and possibly led to negative health impacts to those living around the flare sites.[5] noted that Nigerian government had not enforced environmental regulations effectively due to overlapping and conflicting jurisdiction of separate governmental agencies governing petroleum and the environment as well as non-transparent governance. In the same vein, due to weak regulations and enforcement, operators prefer to flare associated gas than separate it from oil.[37] Furthermore, their focus is to extract the oil, get value for it and flare gas at little cost.[5] In 2016, the minister of state for petroleum resources launched seven initiatives for the petroleum industry in Nigeria, one of which is gas revolution. As a drive towards the gas revolution, the Nigerian gas flare commercialization program was developed, hinged on paragraph 35b of the petroleum act that gives the Government the right to take natural gas produced with crude oil by the licensee or lessee free at the flare or at an agreed cost without payment of royalty. Furthermore, in July 2018, a regulation was passed pursuant to this act called the flare gas (prohibition of wastes and pollution) regulation 2018, which seeks to: allocate flare points that have not received commercial use i.e. seeks to allocate flare points to third party midstream companies who will pay and monetize the gas. Ensure that all new oil and gas development projects have a full proof gas utilization plan with a no flaring policy. Introduce a new flare charge regime to disincentive flaring. The new gas flare charges for oil and gas producers are as follows; with expectation expected that upon implementation of this regulation, operators will be more driven to actualize projects that are flare free: daily production above 10 000 barrel per day (bbl/d)=2 US dollars/1000 standard cubic feet (scf). Daily production less than 10000 bbl/d=0.5 US dollars/1000 scf.

CONCLUSION

This effort appears ineffective due to weak enforcement and poor monitoring mechanism. The statutory government institution entrusted to enforce anti-gas law may benefit from some sort of motivation to ensure oil operators comply to combat environmental health risks from gas flaring. In view of this, the first step towards curbing gas flaring is for Nigerian federal Government is to review fiscal policies that relate to gas flare to increase fines related to gas flaring so that companies invest in gas handling facilities. In addition to reducing the health and environmental consequences of gas flaring, the government can have financial gain from gas sales and monetization initiatives. It is therefore important that the government is proactive to ensure gas utilization schemes are adopted and routine gas flaring is controlled.

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