THE IMPACT OF GAS FLARE ON OIL FIELDS' ENVIRONMENTS

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Abstract - Nigeria, Africa’s most populous nation and leading oil producer with the second-largest natural gas reserves in sub-Saharan Africa, is faced with energy deficiency. Despite efforts to diversify, the economy remains heavily dependent on oil accounting for 85% of government revenues, 99% of export earnings, and 52% of the country’s Gross Domestic Product (GDP). However the exploration and processing systems used to refine oil leads to millions of dollars in waste due to open air burning known as gas flaring rather than harnessing unwanted gases for economic development. Although developed and developing nations have exploited other means of harnessing and harvesting these by-products for energy generation, Nigeria is yet to explore such alternative means hence leading to her sole reliance on hydro-power. This paper attempts to investigate the appropriateness of the oil exploration and exploitation systems used for crude oil production in Nigeria following documentary review of waste gas and the gains that would have accrued had alternative methods of harnessing crude been used as practiced in other parts of the world. This paper concludes that harnessing the waste generated due to open air burning of gases in the Nigerian Delta will provide enough energy that will generate electricity for the entire nation and help elevate lives and businesses.

Key Words - Energy,Gas Flare, Nigerian Delta, Waste Gas and Oil Production

I. INTRODUCTION

Renewable energy is derived from natural sources and processes that are sustainably replenished constantly. In its various forms, it is derived directly or indirectly from the sun, or from heat generated deep within the earth. Energy generated from solar, wind, biomass, geothermal, hydropower and ocean resources, biofuels and hydrogen are derived from renewable resources (IEA 2008a as cited in UNEP, 2011). Although a distinction has been made between natural resources that are exhaustible and have a hazardous effects and those that are not infinite with no adverse effect, both means provide energy sources that are environmentally friendly (Zachary A. Smith & Katrina D. Taylor, 2008). Yet in the Nigerian Delta where gases are regularly flared by companies exploiting oil waste these renewable energy source thereby causing air pollution.

The technologies advanced by alternative sources of energy have over the years created healthy, secure and improved air quality although, the advancement in renewable energy has been due to scarcity and the knowledge/awareness that fossil fuel has a finite life span, which from World Bank calculations, leaves countries with these finite resources a period less than forty years in their reserves. Environmental concerns stimulated harnessing alternative energy sources in order to reduce environmental degradations. As observed by Dincer(1999), renewable energy as a natural resource appears to have advantages in reducing acid rain, precipitation, stratospheric ozone depletion and greenhouse effect. Renewable energy might be efficient in resolving environmental hazards such as gaseous emission in the atmosphere that fall back as acid rain subsequently destroying the built environment causing decay and deterioration on external façades. Nevertheless developing countries like Nigeria who depends on exportation of fossil fuel as an economic livelihood might not be able to sustain its nation although, complete and clean harnessing of waste gases flared will put the nation in an independent and financially balanced state.

II. MATERIALS AND METHODS

“Gas flaring” was used as a search term in major databases including google scholar, web of science, library of congress direct, national archives, scienece.gov, SEO for the period of 1958-2017, and combined with two additional search terms; impact on environment and gas flaring methods. References quoted in the literature and documents obtained from the search were examined.

III. RESULTS

Gas Flaring Process

Flaring of natural or associated gas is done as a by-product of the drilling of crude oil from reservoirs in which oil and gas are mixed. GF is widely used to dispose of dissolved natural gas present in petroleum production and processing facilities where there is no infrastructure to make use of the waste gas. However, innovations and environmental awareness have led to safer methods with open air burning seriously discouraged (Action 2005, Andersen, Assembayev et al. 2012) although Broere (2008) noted that some countries flare gases because of technical,regulatory, or economic constraints.The lack of infrastructure and technological know-how impedes alternative flaring methods in Nigeria.In oil production, the flaring stack equipment is designed in such a way that it is not a source of danger to itself or people working around it through pipe explosions due to the constant flaring from the furnace as shown in figure 1. The gas emerges from crude oil when brought to the surface and is separated from the oil prior to transport.

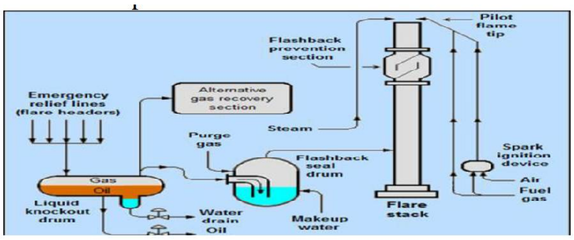

Figure 1 Diagrammatic Description of Gas Flaring Stack
Source: Frede (2008)

The flaring process can produce some undesirable by-products including noise, smoke, heat radiation, light, sulphur oxides (SOx), nitrogen oxides (NOx), carbon monoxide (CO), and an additional source of ignition not desired. While oil exploration and exploitation continue to help nations with needed manpower for economic growth and stabilisation, residues from flaring have become an environmental, physical, economic and social concern, thus the agitation for newer refining methods being explored.

Gas Flaring in Nigeria

There are over 18 multinational oil companies which are involved in oil and gas exploration and production in the ND (Poindexter 2008). Nigeria has a gas reserve of over 110 trillion standard cubic feet (ft^3), about ten times its crude oil reserves (1 barrel of oil equals 3.2 ft^3 gas on chemical conversion basis). In 1989, 617 billion ft^3 of associated gas was flared, releasing 30 million tons of CO and at the end of 1999, cumulative gas production in Nigeria amounted to ca. 27,795.22 Barrels per standard cubic feet (Bscf) of which ca. 23,005.35 Bscf was flared representing 82.8% of the net gas produced (Malumfashi 2007, Nwanya 2011).

Nigeria in the ND flares about 2.5 billion cubic feet per day and has an estimated 106 Trillion m^3 of proven natural gas (Nwanya 2011). Even though, the amount of flared gases could be higher than what is been estimated as affirmed by the Nigerian National Petroleum Cooperation (NNPC) in their 2014 reports (NNPC 2014), the atmospheric disposal of these gases is mostly for emergency as a safety measure. The lack of infrastructures for alternative method(s) results in cheap and easy ways of refining crude oil in order to save the pipes or vessels from over-pressure (Keller, Noble et al. 1990, Nwaugo, Onyeagba et al. 2006). Solov'yanov (2011) and Ite, Ibok et al. (2013) affirmed that more than 250 anthropogenic gases have been identified from flared associated gas like, carcinogens, benzopyrene, benzene, carbon disulphide (CS_2), carbonyl sulphide (COS), and toluene; metals such as mercury, arsenic, and chromium; nitrogen oxides; and sour gas with H_2S and SO_2. Its chemical composition ranges from 95% methane, with 1.5 – 2.0% carbon dioxide, 3.9 – 5.3% ethane, 1.2 – 3.4% propane and1.4 – 2.4% of heavier hydrocarbons. The engineering designs of pipelines are such that the gaseous substances produced by flaring are sometimes colourless, white brown or black. They could either be odourless or with offensive smell from these emissionsas can be seen fromdifferent colours of the smokeat different locations

Figure 2 Red Cycle Showing Carbon Content
Source: limits (2013)

The flaring that occurs as shown in figure 2 is the black coloured flare although flaring is characterised by different colours ranging from colourless to black carbon (Elvidge, Ziskin et al. 2009). Over 50 years since the first discovery of oil in 1958 at Olobiri in the then Rivers state now Bayelsa state, a total of about 1,182 exploration wells have been drilled in the delta basin, and about 400 oil and gas fields of varying sizes have been documented to date (Obaje, 2009). Similarly,Broere (2008)acknowledged that more than 1,000 wells and flaring sites are scattered over an area larger than Portugal.

Impact of Gas Flare on the Built Environment

The affirmation by Odu (1994), The World Bank as cited in Aghalino (2009) and Ekpoh & Obia (2010)has established that acid rain is primarily due to the emission of sulphur dioxide (SO_2) and oxides of nitrogen (NOx) which combine with atmospheric moisture to form sulphuric acids and nitric acids in rain droplets, dew or precipitation. This was supported by the U.S Government's Energy Information Administration, which stated that*; "the continued process of gas flaring has not only meant that a potential energy source- and source of revenue-has gone up in smoke, but it is also a major contributor to air pollution and acid rain"(Environmental Rights Actions 2005).*

Therefore, the chemical composition emitted from flaring has negative environmental consequences in the Environment. The concentration of flaring points in the NDA as illustrated in the satellite imaginary in figure 3 shows that it influences air pollution and affects buildings (Odu 1994, Ojeh 2012, Morrison Ifeanyi and Vincent Nduka 2013). The rampant spread of GF sites in NDA will have an inexhaustible impact on the local environment.

Figure 3 shows the satellite view of GF stacks in the ND area. The yellow light with red lines shows the

NDA and gas flare activities as it lights up the environment even in the dark. As a result, some research describes some areas in ND as the land of no darkness (Ihejiamaizu 1999, Maass 2009). Furthermore, Agbola and Olurin (2003) argue that about 45.8 billion kilo watts of heat are discharged into the atmosphere from 1.8 billion cubic feet of gas daily flared in the ND region, leading to temperatures that render large areas inhabitable. Accordingly, Ite and Ibok, (2013) noted that the ineffective equipment used in the flare systems means that many of them burn without sufficient oxygen or with small amounts of oil mixed with the gas, creating soot deposited on vegetation, buildings and inhaled both indoor and outdoor around any flaring field.

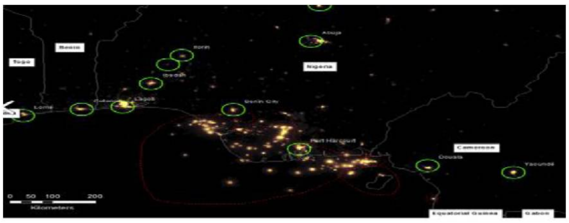

Figure 3 Satellite view of GF stacks in the ND
Source: National Oceanic Atmospheric Administration (NOAA) 2010

Impact of Gas Flares on Buildings

Gas flares produce gaseous substances which combine with atmospheric moistures to deposit these gases through rain droplets, snow, and dew smog on the built environment contributing to different hazards, for instance, corrosion of roofing materials. Although it could be argued that in areas with constant rainfall this effect will not be significant yet corrosion effect has been observed in gas flaring areas of ND as stated by Odu (1994). In addition, changes in colour of the building fabric has been linked to the presence of hydrogen sulphide in the air due to its reaction with a metallic pigment (Ababio, 2005 as cited in Julius, 2011). Similarly, sulphuric acid decomposes cement matrix by decalcifying cement active ingredients such as calcium silicate hydrate (Bassuoni and Nehdi, 2009 and Gao, Yu et al., 2013). Other forms of the disintegration of building materials include the deterioration of the façade painting due to the impact of moisture deformation caused by the moisture drying circle strengthened by acidic precipitation and increment of surface acidic water absorption rate (Alaba 2014). See an example of an impact shown in figure 4.

Figure 4 Deterioration (Flaking) of facade painting
Source: Alaba (2014)

Figure 4 confirmsChew's(2005) findings noting that paint defects, which he referred to as discolouration, peeling and blistering, were observed as serious in buildings. The level of corrosion of corrugated zinc roofing material due to acid rain, the discolouration of other types of roofing materials, heat, discomfort inside of a building, noise pollution due to the pressure from crude oil pipes, sound from furnace of flare stacks, odour are some of the adverse effects of gas flare in the built environment. Similarly, black carbon and fly-ash deposits with the mixture of atmospheric moisture result to discolouration and blackening of roofing materials leading to potential degradation (Ismail and Umukoro, 2012; Jelle, 2012). The chemical composition of gas flares mixed with rain water cause discolouration of roofing materials and deposition of black carbon gives blackening colour to roofing materials causing a negative appearance of buildings; thus the recent agitation of #STOPSOOT in Rivers State.

Impact of Gas Flare on Air Quality

Air quality deteriorates mostly due to industrialisation; population traffic and energy use as stated by Zhao, Chen et al. (2012), while EPA (2013) asserts that the decrease in air quality is because of air pollution. The chemical composition from the exhaust of GF which impacts on air quality and subsequent health conditions includes VOCs and hydrocarbons (containing methane, ethane, propane and buthane, ethylene, butylenes(Kindzierski 1999).The adverse health effect of air quality has been linked with an increase in the number of lung and skin cancer diagnosis (Ana 2011). Many studies and standards have been provided in the developed world to help improve the level of indoor air quality (IAQ) (Conceição and Lúcio, 2006; Rivas et.al. 2004). Countries like the UK and US provide guidelines on the limit of gaseous substances that can be tolerated in an environment with vulnerable people. Table 1 shows gas flare pollutants, their descriptions and adverse health effects.

Pollutant	Description	Adverse Effect
Particulate Matter ($PM_{2.5}$& PM_{10}):	PM affects more people than any other pollutant. The major components of PM are sulphate, nitrates, ammonia, sodium chloride, black carbon, mineral dust and water. It consists of a complex mixture of solid and liquid particles of organic and inorganic substances suspended in the air.	The most health-damaging particles are those with a diameter of 10 microns or less, ($\leq PM_{10}$), which can penetrate and lodge deep in the lungs. Chronic exposure to particles contributes to the risk of developing cardiovascular and respiratory diseases, as well as of lung cancer.
Carbon monoxide (CO)	A colourless, odourless gas that interferes with the delivery of oxygen throughout the body.	Carbon monoxide causes headaches, dizziness, weakness, nausea, and even death

Nitrogen dioxide (NO_X)	Colourless, odourless gas	Epidemiological studies have shown that symptoms of bronchitis in asthmatic children increase in association with long-term exposure to NOx. Reduced lung function growth is also linked to NOx and causes eye, nose and throat irritation, shortness of breath, and an increased risk of respiratory infection
Volatile organic compounds (VOCs)	VOCs evaporate into the air when these products are used or sometimes even when they are stored	Volatile organic compounds irritate the eyes, nose and throat, and cause headaches, nausea, and damage to the liver, kidneys, and central nervous system. Some of them can cause cancer
Ozone (O_3)	Excessive ozone in the air can have a marked effect on human health.	It can cause breathing problems, trigger asthma, reduce lung function and cause lung diseases
Benzene	Benzene in indoor air can originate from outdoor air. Indoor concentrations are also affected by climatic conditions and the air exchange rate due to forced or natural ventilation	Human exposure to benzene has been associated with a range of acute and long-term adverse health effects and diseases, including cancer and aplastic anaemia. Acute exposure to benzene may cause narcosis: a headache, dizziness, drowsiness, confusion, tremors and loss of consciousness, moderate eye irritant and a skin irritant
Sulphur Dioxide (SO_2)	Gases formed by incomplete combustion of all carbon fuels.	SO_2 can affect the respiratory system and the functions of the lungs, and causes irritation of the eyes. Inflammation of the respiratory tract causes coughing, mucus secretion, aggravation of asthma and chronic bronchitis and makes people more prone to infections of the respiratory tract.
Polycyclic Aromatic Hydrocarbons	PAHs are a class of organic compounds produced by incomplete combustion or high-pressure processes. PAHs form when complex organic substances are exposed to high temperatures or pressures.	Short-term exposure to PAHs also has been reported to cause impaired lung function in asthmatics and thrombotic effects in people affected by coronary heart disease, eye irritation, nausea, vomiting, and diarrhoea. Long-term exposure to PAHs has been reported to have an increased risk of skin, lung, bladder, and gastrointestinal cancers.
1,3-butadiene	A product of incomplete combustion resulting from natural processes and human activity1, 3-butadiene is also a recognised genotoxic human carcinogen, as such, no absolutely safe level can be specified.	The health effect of most concern is the induction of cancer of the lymphoid system and blood–forming tissues, lymphoma and leukemia

Table 1: Gas Flare Pollutants and their Adverse Effects
Source: Alder (2000), EPA (2008)

Various studies have shown that poor IAQ can havedifferentadverse effects and can cause discomfort, irritation, and various short and long-term health problems (Mustapha et.al, 2011). Therefore, GF environment requiresstringent laws to regulatecrude oil exploration through sustainable means.

Gas Flaring Reduction Methods

Although oil exploration and exploitation has continued to help many nations with economic growth and stabilisation, residues from flaring have become an environmental, physical, economic and social concern. Despite this fact most countries in the world that produce oil flare gases and the twenty most flaring nations in the world are illustrated in figure 5.

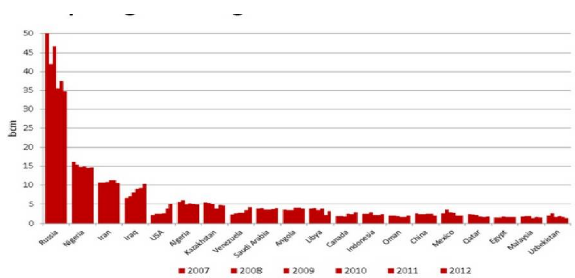

Figure 5 Top 20 Gas Flaring Countries
Source: World Bank report (2016)

Figure 7 shows all flaring amounts in Billion Cubic Metres (BCM) with Russia being the highest followed by Nigeria with Uzbekistan being the least flaring nation with less the 5BCM. As a result, thousands of gas flares at oil production sites around the globe burn approximately 140 billion cubic meters of natural gas annually, causing more than 300 million tons of CO^2 released into the atmosphere (World Bank report 2016). Though, reports from different studies indicate that flaring is either reducing or at a stable rate over recent years (Andersen, Assembayev et al. 2012, Anejionu, Blackburn et al. 2015), there is theneed to further reduce gas flaring as its adverse impact has continued to make waves; the rising concerns of its effect on a global scale.The World Bank, in 2016, noted 4 common features of successful anti-flaring options:

1. Anti-flaring legislation accompanied by public reporting and monitoring
2. Flexible approach that adapts to specific field circumstances
3. Open and transparent access to pipelines and other infrastructure
4. Independent pipeline regulatory body with effective enforcement capability and capacity for quick response, based on international best practices. This body should be independent of influence from current and future participants. It could be a completely separate organization or be part of the government.

Furthermore, some countries which have had successful reductions in GF achieve these by adopting and using additional features as listed in table 2

No	Country	Anti-Gas Flaring Features
1	Norway	➢ Government directly regulates emissions through development and operational plans and environmental impact assessments ➢ Transparent process includes public consultation ➢ Open-access gas infrastructure jointly owned by multiple producers (replacing an earlier system in which Station oil control of the infrastructure blocked access for other producers) ➢ CO2 tax provides additional incentives ➢ Flaring restrictions are credited with creating incentives to develop gas infrastructure, enhanced recovery, and new technology such as "closed flare systems"
2	UK	➢ Policies designed to maximize economic recovery of oil and gas reserves and reduce greenhouse gas emissions ➢ Department of Trade and Industry (DTI) controls all flaring and venting through Licensing and Consents unit ➢ DTI reviews all Field Development Plans, which must consider feasibility of APG utilization all but the smallest fields also require Environmental Impact Assessments ➢ Annual reporting required from all fields ➢ Flare Transfer Pilot Trading Scheme designed to further reduce gas flaring ➢ Third party access to upstream gas pipelines ➢ Unbundled midstream/downstream markets
3	Alberta, Canada	➢ Flaring regulated by province rather than the federal government ➢ Reduction of gas flaring is a priority of the Alberta Energy and Utilities Board (EUB) ➢ EUB requires operators to assess alternatives to flaring and venting ➢ Latest EUB directive requires operators to eliminate flaring even when this requires some subsidy ➢ Annual and public reporting requirements and periodic inspections ➢ Enforcement ladder system with escalating consequences for non-compliance ➢ Liberalized gas markets and open pipeline access with regulated tariffs ➢ Royalty waiver program designed to further reduce flaring
4	US	➢ Environmental Protection Agency regulates some APG components, but not methane itself ➢ Offshore operations regulated by federal Minerals Management Service (MMS), which permits only very limited gas flaring ➢ MMS requires monthly production statements, including flared gas volumes ➢ Bureau of Land Management also has flaring regulations and reporting requirements ➢ Individual states have rules and regulations governing flaring and venting ➢ Highly developed hydrocarbons markets and transportation infrastructure with open access

Table 2: Countries with Successful Reduction in Gas Flaring
Source: The World Bank Group (2016)

Based on the table above countries are making progress from partnership with stakeholders including government and individual investors including locally based subsidies and incentives to promote investment in harnessing the waste gas for economic gains. The economic feasibility of other methods of oil exploration might also be a significant reason for flaring as affirmed by World Bank (2004). For instance, since 2005 Russia has been flaring up to 15BCM and increased to 20BCM in 2007 even though there was a promise of the possible reduction in GF (Loe and Ladehaug 2012). Again, Knizhnikov and Poussenkova (2009) purport that only half of the flares have flow monitors in Russia. Therefore based on World Bank (2004) at cited above, the economic feasibility could be the significant reason in the high level of flaring in Russia. Although, these reasons fall short of the purpose why gases are constantly flared in the Nigerian delta as the Stop Gas Initiative is continually moved forward with no real actualisation seen in the country.

CONCLUSION

The studyhas shown that gas flaring impacts on the environmnet negatively and as such countries are exploring newer methods of hanessing natural gases with conversion possiblities to renewable energy and have shown positive gains. The possibility of havesting and turning waste gas which degrades and contaminates the environmnet to reduce the liveablehood of the populace who supposedly should enjoy the benefits is a menace that has to be checked and require urgent consideration. While the economic, social and environmnetal gains are acruable, if alternative exploration system of gas flaring is used,the urgency and health implicaton is a worrisome sequence that needs to be the motivating factor rather than the easy way out based on the continued excuses of the lack of infrastructure to enable uterlisation.

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