GEOSPATIAL VARIATION OF WEATHER PARAMETERS AND AIR QUALITY AT OLOGBO FLOW STATION IN EDO STATE, NIGERIA

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Abstract: One of the characteristics of petroleum industry in developing countries is incessant flare of gases with its attendant socio-ecological impacts. Gas flaring has not only contributed to poor environmental quality and pollution but play remarkable role in micro-climate modification. The aim of this study was to examine the effects of gas flaring on air quality of Ologbo flow station, Edo state. Data was collected for air within defined distances from the flaring point in accordance with standard procedure. A 4 km distance from the flare facility was buffered. Sampling sites 1, 2, and 3 are within the vicinity of the flare facility, while the control point (Evbuarhue) is located 30 km from the fence of the flare facility. Air Quality measurements were done for carbon monoxide (CO), nitrogen dioxide (NO_2), methane CH_4 and ammonia (NH_3) using toxic gas monitors meter; toxic EEX 79 IICT3-T4 and CE89/336/EEC. The Ambient Air Quality and humidity were analyzed in situ using the standards adopted by the Federal Ministry of Environment. Temperature was discovered to have risen by 10^0C at station 1. Relative humidity was recorded as 63%. Average total suspended particulates, nitrogen dioxide, carbon monoxide, sulphur dioxide ammonia and methane were recorded as 2.25, 1.2, 3.0, 0.014, 0.01 and 0.01 ppm, respectively. These values exceeded results obtained at control site. Standard deviation varied from 1.35 for temperature, 7.8 for relative humidity, 1.19 for total suspended particulates, 0.84 for nitrogen dioxide, 1.87 for carbon monoxide, 0.007 for sulphur dioxide and 0.00 for ammonia and methane. With continuous flare of gas, the study area will over time undergo further alterations in its air quality.

Keywords: Air quality, Ologbo flow station, pollution, weather parameters

Introduction

The world is blessed with abundant of oil and gas resources to meet the increasing energy needs. Statistics show that at the end of 2017, the global gas reserves stood at 193.5 trillion cubic meters (British Petroleum – BP, 2018). Out of this figure, about 80% were found in just ten countries including Russia, Iran, Qatar, Turkmenistan, United States of America (USA), Saudi Arabia, United Arab Emirates (UAE), Venezuela, Nigeria and Algeria in decreasing order (Duddu, 2013). In terms of production and consumption, about 3680.4 billion cubic meters were actually extracted, 3670.4 billion cubic meters consumed (BP, 2018) and the rest unutilized and in most cases flared. Thus, based on Giwa *et al.* (2017), gas flaring is "the speedy oxidization of natural gas with simultaneous emission of gaseous, particulate and heat into the atmosphere". Thus, reducing the flaring of natural gas has been an issue of global concern in recent years due to its attendant impacts on humans and environment.

According to the World Bank (2016), "about 147 billion cubic meters (bcm) of natural gas was flared in 2015 up from 145 bcm in 2014 and 141 bcm in 2013 globally. Russia remains the world's largest gas flaring country, flaring about 21 bcm annually, followed by Iraq (16 bcm), Iran (12 bcm), USA (12 bcm), and Venezuela (9 bcm)". Giwa *et al.* (2017) reported that "out of the 1.78 trillion cubic meters of gas produced in Nigeria's Niger-Delta region between 1965 – 2015, about 822.02 bcm utilized and 917.17 bcm were flared. In any given flaring event, several harmful substances including hydrogen sulfide, toluene, benzene, sulphur dioxide, benzapryene, nitrogen dioxides, xylene, among others are emitted into the atmosphere (International Climate Fund – ICF, 2006). The composition and magnitude of natural gas flared is a function of the quantity and category of pollutants released into the atmosphere coupled with the flare architecture, burning parameters as well as the local weather patterns (Torres, Herndon and Allen, 2012; Fawole *et al.*, 2016). These harmful substances therefore constitute key air quality issues in both developed and developing countries and according to Giwa *et al.* (2017) "the most important contributor to global warming and climate change".

In Nigeria, natural gas is found with hydrocarbon (crude petroleum). Thus, when crude oil is extracted, it often comes with associated gas which must be separated from the crude to produce fine, export quality petroleum products. A common practice is to burnt off as unusable waste gas or flammable gas, which is released by pressure relief valves during unplanned over-pressuring of plant equipment. It burns through a flare stack (an elevated vertical chimney) on oil wells, in refineries, in chemical plants or in a flow station as seen in Plate 1.

Plate 1: Gas flare stark at NPDC flow station in Ologbo, Edo State (Damiete, 2017)

The proponents of gas flaring in the upstream sector of the petroleum link it to system safety and framework to protect vessels or pipes from over-pressuring due to unplanned upsets. Whenever the plant equipment items are over-pressured, pressure relief valves automatically release gas (and sometimes also liquids). The released gases and/or liquids are burnt as they exit the flare chimney. The size and brightness of the resulting flame depend upon the amount of released flammable material. Steam can be injected into the flame to reduce the formation of black smoke. In order to keep the flare system functional, a small amount of gas is continuously burnt, like a pilot light, so that the system is always ready for its primary purpose as an over-pressure safety system (Milton, 2005).

Nevertheless, the earliest moves at commercializing natural gas were made by Shell/BP in 1960 with an agreement to supply gas to some manufacturing units in Aba, south eastern Nigeria and the State owned Power Company then called Electricity Corporation of Nigeria, for thermal electricity generation. In 1995 British Gas Corporation indicated its intentions to buy Nigeria's Liquefied Natural Gas and this gave Nigeria the impetus to consider a proposal to explore her gas reserves. Unfortunately, with the discovery of commercial quantity of natural gas in the Southern North Sea, the corporation suspended discussions on the project (Okoh, 2001). The production of gas, despite record of huge association and non-associated gas reserves, has been low while its commercial exploration for domestic use and export has never been anywhere close to that of oil, rather flaring of associated gas has been the norm (Bankole, 2001). Recently, "among the large flaring countries, Nigeria has made significant progress, reducing flaring by 18 percent since 2013, to less than 8 bcm in 2015" (World Bank, 2016).

Continuous flaring does not only pollute the immediate environment of the host community but, also contribute in increasing the levels of atmospheric greenhouse gases that result in increasing temperature. Greenhouse gases are gases in our atmosphere that serve to regulate the amount of heat that is kept close to the Earth's surface. Scientists theorize that an increase in these greenhouse gases will translate into increased temperatures around the globe, which would result in many disastrous environmental effects. According to Nordell (2003), this warming is a result of heat emissions from the global consumption of non-renewable energy. The Intergovernmental Panel on Climate Change (IPCC) (2007) in its fourth assessment report revealed that 1995-2006 ranked among the twelve warmest years in the instrumental record of global surface temperature since 1850.

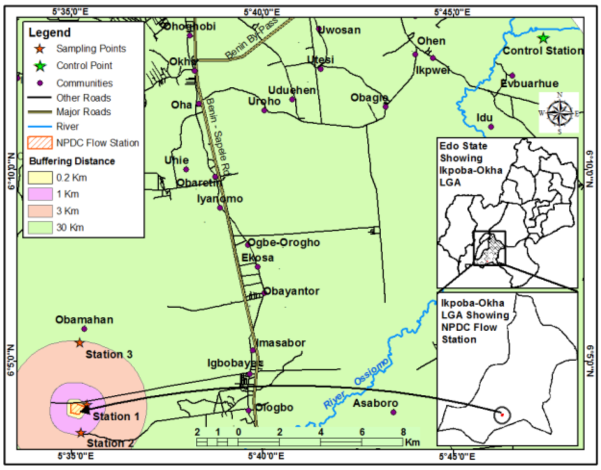
Indeed, for quite sometimes now, the residents of close communities to gas flare points in the Niger Delta have been vocal on the effect this pollution has on the health of the citizens as well as their metallic (galvanized iron) roofs (Obia, 2009; Uyigue and Agho, 2007). Health problems often associated with gas flaring include asthma and such respiratory illnesses as chronic bronchitis, coughing and wheezing, difficulty in breathing; sometimes leading to such complications as impotency, blindness and premature death (USEPA, 2007; Palmer, 2009; Ekpoh and Obia, 2010). The communities' position especially as it relates to galvanized iron roof corrosion had always been countered by the simple argument that Nigeria's crude oil is low in sulphur content and would not produce sulphur dioxide in a volume that could be detrimental to materials (Inyang, 2001; Obia, 2008).

The reduction of greenhouse gas emissions has become a primary focus of environmental programs in countries around the world. Nigeria's South-South Region (Niger Delta) has been at the fore of international attention in recent time. Most of the discussions have been on oil spill and the associated ecological impact on the rich ecosystem of the mangrove environment. In recent time however, world attention driven more by the threatening global warming has shifted to air pollution in the Delta perceived to be a major contributor to the planetary atmospheric carbon dioxide imbalance. This study intends to investigate fully the effects of gas flaring on the quality of air in Ologbo community, Edo state.

Materials and Methods

The NPDC Flow Station is located between latitudes 6^0 3' 31.68'' – 6^0 3' 57.6''North of Equator and longitudes 5^0 34' 52.74'' – 5^0 35' 26.88''East of Greenwich and in the heart of Ossiomo industrial park in Ologbo community, Ikpoba-Okha Local Government Area (LGA) of Edo State. It is about 35 km from Benin City, the capital and about 35 km from Koko, Delta State. The climate of the area is an equatorial characterized by double rainfall maxima with an alternating wet and dry season influenced by its proximity to the Atlantic Ocean, wind patterns and sunshine. The National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR) data of Ologbo covering 36-year period of 1979 through 2014 reveals that the mean maximum temperature is 31.4^0C, mean minimum temperature is 22.3^0C and mean precipitation is 744.0 mm. Also, mean wind speed stood at 1.24 m/s^2, mean relative humidity (83%) while mean solar radiation (17.1 MJ/m^{-2}). In 1991, the demographic characteristics of the host community, Ologbo show that they were 10,022 people divided into 5,437 males and 4,585 females. With a rural population growth rate of 2.8%, the 2017 population projection of the community stood at 20,548 with 11,148 males and 9,400 females. Major occupation of the people is small scale farming.

Data was collected for air within defined distance from the flaring point. To define the sample area, the approach of proximity to flaring facility as defined by Argo (2002) was adopted. According to (Argo, 2002), proximity to gas flaring point is any distance within 0.2 to 35 km from the flare stack (Ovuakporaye, 2012). Following this definition, a 4 km distance from the flare facility was buffered. Within this specified zone (4 km), air samples were collected and quality analysis at different intervals for the purpose of detecting variations. In addition, control point was also established. Control point for air was established at 30 km from the fence (bund wall) of the flare facility and 27 km from the buffered sampling area (3 km) as shown in Fig. 1. Sampling sites 1, 2, and 3 are within the vicinity of the flare facility, while the control point (Evbuarhue) is located 30 km from the fence of the flare facility. The distance of the control site was chosen because Onuorah (2000) and Odjugo (2007) noted that the impact of gas flaring on the atmospheric quality is statistically insignificant beyond 15 and 20 km radius of the flare site. Buffering of sampling area was conducted using the geographic information system technology.



Source: Field Work (2017)

Fig. 1: NPDC Ologbo Flow Station showing sampling points and control point

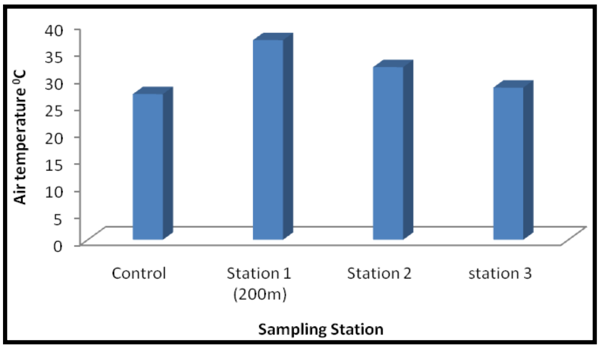
A total of four monitoring sites were established. These include 200 m from the Bund wall (fence of flow station) 1, 3 and 30 km (control point) i.e. 27 km from the buffered area (3 km). The SKC (support knowledge choice) pumps were used for the measurement of suspended particulate. The sampling meter was held at a height of approximately 1.5 meters above the ground. Air Quality measurements was made for CO, NO_2, CH_4 and NH_3 using toxic gas monitors meter; toxic EEX 79 IICT3-T4 and CE89/336/EEC.

The Ambient Air Quality was analyzed in situ using the standard adopted by the Federal Ministry of Environment, Housing and Urban Development (FME & UD). The FME & UD adopted the World Health Organization (WHO) standards as the national standards for gaseous emissions against which air quality parameters monitored are compared in order to ascertain its "cleanliness".

Results and Discussion

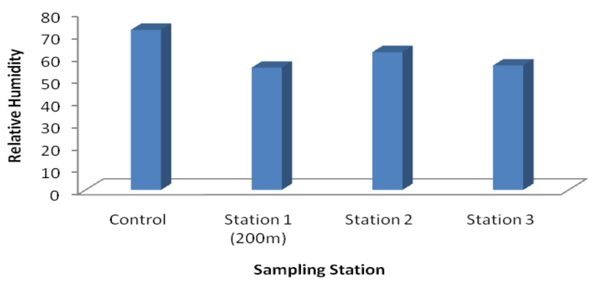
Ambient air temperature

The impact of air emission on ambient air temperature in the vicinity of the flow station at the different sample points was presented as figure v. From the figure, it can be seen that temperature was highest at station 1 which is 200 m (37^0C) from the fence of the flow station. Observed air quality in the vicinity of flow station was compared with air quality at control sites. Temperature at station 1 was recorded as 37^0C which is higher than 27^0C recorded at the control site. There was however gradual decrease in temperature away from the bund wall with the lowest temperature value being recorded at station 3 with surface temperature of 28.5^0. If the experimental station 1, 2, 3 and control recorded 37, 32, 28.2 and 27^0C (control) then the flare had increased the temperature of the stations by 10^0C (200 m), 5^0C (1 km), and 1.2^0C (3 km). Temperature can be said to decrease as one move away from the flare site (Fig. 2). Thermal air pollution occurs if the recorded air temperatures of the place deviate from its normal ambient temperature (Oseji, 2010). Similarly, Odjugo (2009) observes that gas flaring increased air (Efe and Ojoh, 2011). Similarly, the excessive and continuous heating, not only reduces the soil moisture but also affects the photoperiodicity required for plant flowering and fruiting (Botkin and Keller, 1998).



Source: Field Work (2017)

Fig. 2: Impact of gas flaring on Air temperature



Source: Field Work (2017)

Fig. 3: Impact of gas flaring on relative humidity

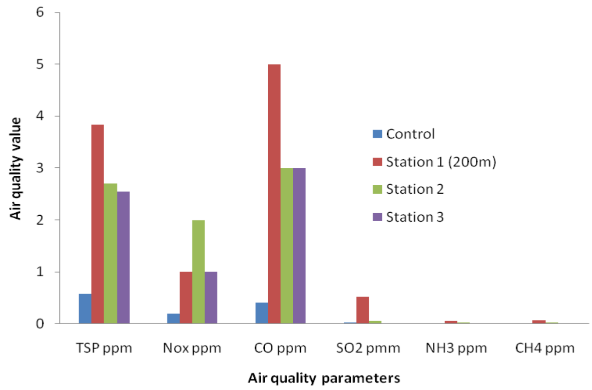
Relative humidity

Humidity value was observed to be highest at the control as seen in Fig. 3. Station 1 recorded the lowest value of humidity which is followed by station 3. There was a rise in relative humidity at station 2 which can be related to the presence of strong lapse condition (looping) with moderate to high wind velocity and large convective mixing of air (Ayoade 1993). The relative humidity tends to decrease as one move towards the flare site. Relative humidity tends to follow closely the reverse pattern of temperature which increased with increasing distance from the flare site. Since relative humidity is affected by ambient temperature, it follows therefore that the higher the temperature as one moves from flare site, the lower the relative humidity. The higher temperatures generated by the flare must have increased the evaporation rate (Odjugo, 2007), in sites closer to the flare hence decreased the relative humidity which will in turn reduce the soil moisture.

Other air quality parameters

There was observed significant spatial variation in levels of the air quality due to dispersal of aerial materials from point sources of pollution. Notwithstanding, values obtained for CO, NO_2, SO_2 and CH_4 from Ologbo flow station were above values obtained at Evbuarhue (being the control point) which include 0.4, 0.2, 0.02 and 0.01 ppm for CO, NO_2 SO_2 and CH_4, respectively.

The values of all the air quality indices decreased with distance from the flow station site, indicating that air emission diffusion increased with increasing distance (Craft *et al*., 1986). This observation is attributed to the high pollution level due to activity of the flow station in Ologbo community (Fig. 4).



Source: Field Work (2017)

Fig. 4: Impact of gas flaring on other air quality parameters

Nevertheless, it was observed that station 1 with a value of 1 ppm recorded the same value of nitrogen dioxide with station 3, while station 2 with a value of 2 ppm recorded the highest value of nitrogen dioxide. This pattern of observed low concentration of light pollutants close to the bond wall and somewhat increase some distance away, with a sort of lowering again can be attributed to strong lapse condition (looping) (Ayoade, 1993). Nitrogen dioxide concentration was far less at the control point which is 0.2 ppm, relative to areas within the flare vicinity but above the upper limit of the Federal Ministry of Environment of Nigeria. The values of Nitrogen dioxide at the sampling points are clearly above the 0.06 upper limit of the Federal Ministry of Environment of Nigeria (FMENV, 2001).

Carbon monoxide CO was seen to be highest in station1 with a value of 5ppm, while values in stations 2 and 3 recorded the same value which is 3 ppm. The control point has a very insignificant concentration of Carbon monoxide of 0.4 ppm compared to areas within the flare vicinity, indicating that the flow station environment is polluted by flare activities. This finding is in agreement with Onuorah (2000) and Odjugo (2007) who noted that the impact of gas flaring on the atmospheric quality is statistically insignificant beyond 15km and 20km radius of the flare site. According to research, carbon-monoxide and related trace metals have been linked with both acute and chronic adverse health effects which mostly include respiratory diseases, lung cancer, heart diseases and damage to other organs (Prieditis and Adamson, 2002; Magas *et al*., 2007; Wild *et al*., 2009).

Other air quality indices such as Ammonia, sulphur dioxide and methane were generally low in all the sample points. The low concentrations of sulphur dioxide at the experimental points justify the UNEP (1983) assertion that SO_2 is mainly emitted into the atmosphere via fossil fuel combustion especially coal. Volatile sulphur is low in the flared gas and would not be expected to contribute much to the acidity of rainwater. In the air, sulphur dioxide produced as a result of gas flaring converts to sulphur trioxide (SO_3) and sulphate particles (SO_4) which is a highly corrosive substance (Overrein *et al*., 1980).

Value of total suspended particulate was observed to be highest at station 1 with a value of 3.83 ppm, which gradually decreased in stations 2 with a value of 2.7 ppm and station 3 with a value of 2.55 ppm. The concentration of Total Suspended Particulate at the control is highly insignificant with a value of 0.58ppm. The TSP values obtained in this research compared well with other similar research works that have been carried out in some parts of Nigeria (Ukpebor *et al*., 2004; Efe, 2006; Ediagbonya *et al*., 2012, 2013) though lower than most of those values, reason being that Isoko land is more of a rural area, but the values obtained were higher than those obtained from similar research works done in some advanced countries such as England, Australia, and Mexico (Sato *et al*., 1995; Butler and Crossley 1979; Verrall *et al*., 1986; Goodman, 1977; Zhao and Zhao, 2012; Putaud *et al*., 2010); more stringent laws governing oil and gas activities as well as air pollution, also the good condition of infrastructure in those countries.

Airborne particulate matter contains a large number of genotoxic and carcinogenic substances, such as, the polycyclic aromatic hydrocarbons (PAHs). Particulate matter has been linked to premature mortality, lung cancer, respiratory and cardiovascular health problems (Sufian, 2011). Long-term exposure to particulate matter <10 mm in diameter had a significant negative effect on lung-function proxy for the development of large (forced expiratory volume in one second) and small (mid-expiratory flow between 25 and 75% of the forced vital capacity) airways, respectively (Horak *et al*., 2002). Particulates are especially dangerous because they have been implicated in the development of lung cancer and higher rates of mortality (Schwela, 2000).

Conclusion/Recommendation

The impact of flares on air quality in the vicinity of the flow station at the different sample points showed that air quality within the buffer of the flow station is polluted when compared to air quality at the control site. Temperature was observed to have increased as one move away from the flare site; there was 10°C increase in temperature close to the bund wall. There was however gradual decrease in temperature away from the bund wall of the flow station with the lowest temperature value being recorded at station 3(the buffer station). Areas close to the flow station (the buffered area) experienced increased temperature due to the heat generated by flaring activities. The sampling point closest to the bund wall (200 m) experienced 37°C as its temperature with a difference of 10°C from the second sampling point (1 km away) which experienced a temperature of 27°C.

Relative humidity was observed to follow closely the reverse pattern of temperature by decreasing towards the flare site which connotes that the high temperature generated by the flare must have increased the evaporation rate, thus decreasing the relative humidity. Values of nitrogen dioxide (NO_2), total suspended particulate (TSP), Carbon monoxide CO, Ammonia, sulphur dioxide and methane were generally low in all the stations when compared to patterns observed for temperature and humidity.

A clear trend was observed as flaring is seen to affect the air quality of the vicinity of the flow station without a specific pattern due to the effect of wind action and dispersal (plume system) and other factors. The values of all the air quality indices decreased with distance from the flow station site with the exception of relative humidity indicating that air emission diffusion increased with increasing distance. This research herby recommends that gas flaring should be stopped.

Conflict of Interest

Authors declare that there is no conflict of interest reported on this work.

References

Ayoade JO 1993. *Introduction to Climatology of the Tropics*. John Wiley, London.

Bankole AS 2001. Incentives and Regulations to Abate Gas Flaring in Nigeria: Towards an Optimal Gas Utilization Policy. In: Nigeria Economic Society (NES), *Natural Resources Use, the Environment and Sustainable Development*. Ibadan: NES, pp. 519-534.

Botkin DB & Keller EA 1998. *Environmental Science Earth as a living Planet*. 2nd Edition John Wiley and Sons Canada.

British Petroleum 2018. Statistical Review of World Energy 2018 (67th edition). Accessed 7th July, 2018. https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review/bp-stats-review-2018-natural-gas.pdf

Butler JD & Crossley P 1979. An appraisal of relative airborne suburban concentrations of polycyclic aromatic hydrocarbons monitored indoors and outdoors. *Science and Total Environment*, 11: 53-58.

Craft WA, Janvia BB & Yatawara CS 1986. Airborne out-break of *Ireitcothein toxicosis*. *Atmospheric Environment*, 20: 516-522.

Damiete E 2017. Gas Flare Stark at NPDC Flow Station in Ologbo, Edo State. Accessed 7th July, 2018. https://www.google.com/maps/@6.0643797,5.583812,3a,75y,90t/data=!3m7!1e2!3m5!1sAF1QipMUxN4Hq9G1ojnz0XceF-KsKqF8GAiImsmwUK5!2e10!6shttps:%2F%2Flh5. googleusercontent.com%2Fp%2FAF1QipMUxN4Hq9G1ojnz0XceF-KsKqF8GAiImsmw UK5%3Dw365-h269-k-no!7i943!8i695

Duddu P 2013. The world's biggest natural gas reserves. Accessed 7th July, 2018. https://www.hydrocarbons-technology.com/features/feature-the-worlds-biggest-natural-gas-reserves/

Ediagbonya TF, Tobin AE & Ukpebor EE 2013. The level of suspended particulate matter in wood industry (sawmills) in Benin City, Nigeria. *J. Envtal. Chem. and Ecotoxicol.*, 5(1): 1-6.

Ediagbonya, T., Ukpebor, E. E., Okieimen, F. E and Okungbowa, G. E. (2012). Comparative study of TSP, inhalable particles and respirable particles in urban and rural areas in Niger Delta Region of Nigeria. *Greener J. Physical Sci.*, 2(3): 089-096.

Efe SI 2006. Particulate pollution and its Health Implications in Warri Metropolis, Delta State, Niger. *Environmental Analysis*, 11: 1339-1351.

Ekpoh IJ and Obia AE 2010. The role of gas flaring in the rapid corrosion of zinc roofs in the Niger Delta Region of

Nigeria. *Environmentalist*, 30: 347-352. doi: 10.1007/s10669-010-9292-7.

Giwa SO, Nwaokocha CN, Kuye SI & Adama KO 2017. Gas flaring attendant impacts of criteria and particulate pollutants: A case of Niger Delta region of Nigeria. *Journal of King Saud University – Engineering Sciences*, http://dx.doi.org/10.1016/j.jksues.2017.04.003

Goodman HS 1977. Particulate concentration in air in eastern Australia and Papua New Guinea, *Clean Air*: pp. 40-43.

Horak F, Studnicka M, Gartner C, Spengler JD, Tauber E, Urbanek R, Veiter A & Frischer T 2002. Particulate matter and lung function growth in children: A 3-yr follow-up study in Austrian schoolchildren. *European Respiratory Journal*, 19: 838-845.

Intergovernmental Panel on Climate Change (IPCC) 2007. Climate Change 2007: Synthesis Report. Summary for Policy Makers. Accessed 7th July, 2018. http://www.ipcc-wg1-ucar.edu/wg1-report.htm.

International Climate Fund (ICF) 2006. *Nigeria: Guidebook for Carbon Credit Development for Flare Reduction Projects*. Abuja, ICF.

Inyang L 2001. Air quality, precipitation and corrosion studies confirm no impact from QIT flare on roofing sheets. *Exxon Mobil News*, September – December.

Magas OK, Gunter JT & Regens JL 2007. Ambient air pollution and daily pediatric hospitalizations for asthma. *Envtal. Sci. and Poll. Res.*, 14: 19-23.

Milton R & Beychok O 2005. *Fundamentals of Stack Gas Dispersion* (Fourth edition ed.). self-published. ISBN 0-9644588-0-2. http://www.air-dispersion.com/ See Chapter 11, Flare Stack Plume Rise.

Nordell B 2003. Thermal Pollution Causes Global Warming. *Global and Planetary Change*, 38: 305-312.

Obia AE 2009. The effect of industrial air-borne pollutants on the durability of galvanized iron roofs in the tropical humid region of Nigeria. *Global Journal*, 8(2): 79-83.

Odjugo PAO 2007. Some effects of gas flaring on the microclimate of yam and cassava production in Erhorike and Environs, Delta State, Nigeria. *Nig. Geograp. J.*, 5: 43-54.

Odjugo PAO 2009. Quantifying the cost of climate change impact in Nigeria: Emphasis on wind and rainstorm. *Journal of Human Ecology*, 28(2): 93-101.

Okoh RN 2001. Cost-Benefit Analysis of Gas Production in Nigeria. In: Nigeria Economic Society (NES), *Natural Resources Use, the Environment and Sustainable Development*. Ibadan: NES, pp. 389-412.

Onuorah AO 2000. The oil industry and environmental degradation. *J. Atmospheric Sci.*, 10: 42–63.

Oseji JO 2010. Thermal gradient due to gas flared at Koko-ri/Erho-ike Flow Station, Delta State, Nigeria. *The Pacific J. Sci. and Techn.*, 11(2): 18-121.

Overrein LN, Seip HM and Tollan A 1980. Acid precipitation - effects on forests and fish. Final report of the SNSF - Project 1972-1980.

Ovuakporaye SI 2012. Effects of Prolong Exposure to gas faring on the mean peak expiratory flow rate of residents in gas flaring community in Delta State, Nigeria. *J. Sci. and Multidiscipl. Res.*, 4: 16-21.

Palmer P 2009. Niger Delta's mangrove communities threatened by gas flaring. Accessed 7th July, 2018. mhtml:file://Niger Delta's mangrove communities threatened.

Prieditis H & Adamson IY 2002. Comparative Pulmonary toxicity of various soluble metals found in urban particulate dust. *J. Experimental Lung Res.*, 28(7): 563-576.

Putaud JP, Van DR, Alastuey A, Bauer H, Birmili W, Cyrys J & Raes F 2010. A European aerosol phenomenology–3: Physical and chemical characteristics of particulate matter from 60 rural, urban, and kerbside sites across Europe. *Atmospheric Environment*, 44(10): 1308-1320.

Sato M, Valent G, Coimbrao CA, Coelho MCLS, Sanihez P, Alonso CD, Martins MT 1995. Mutagencity of air borne particulate organic material from urban and industrial areas of Sao Paulo, Brazil. *Mutation Research*, 335: 317-330.

Schwela D 2000. Air pollution and health in urban areas. *Revolution and Environmental Health*, 15(1-2): 13-42.

Sufian ME 2011. Airborne particulate matter (PM10) composition and its genotoxicity at two pilgrimage sites in Makkah, Saudi Arabia. *J. Envtal. Chem. and Ecotoxicol.*, 3(4): 93-102.

Torres VM, Herndon S, Allen DT 2012. Industrial flare performance at low flow conditions. Steam-and air-assisted flares. *Ind. Engr. and Chem. Res.*, 51(39): 12569– 12576.

Ukpebor EE, Ukpebor JE & Efebomo G 2004. Assessment of the effect of medical waste incinerator on the ambient dose of TSP and NO2. *Int. J. Chem.*, 14(2):111-117.

United Nations Environmental Program (UNEP) 1989. First Meeting of Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer, Helsinki Declaration on the Protection of the Ozone layer, Helsinki, Finland, 2-5 May. New York, UNEP. Available at: https://unep.ch/ozone/Meeting_Documents/mop/01mop/MOP_1.shtml

USEPA 2007. Effects of acid rain. Accessed 7th July, 2018. http://www.epa.gov/acidrain/effects

Uyigue E & Agho M 2007. Coping with climate change and environmental degradation in the Niger Delta of southern Nigeria. Community Research and Development Centre, Benin City, Nigeria.

Verrall KA, Muller WA, Kingston PA, Rose HC & Raftery NA 1986. Identification of Sources Contributing to Total Suspended Particulates in Brisbane. Proceedings of Clean Air Conference. Clean Air Society of Australia and New Zealand, Sydney, pp. 290-291.

Wikipedia (a) 2010. Environmental Issues in the Niger Delta. Retrieved from http://en.wikipedia.org/wiki/sustainability/(19/9/2010)

Wild P, Bourgkard E & Paris C 2009. Lung cancer and exposure to metals: The epidemiological evidence. *Method Molecular Biology*, 472: 139–167.

World Bank 2016. New Data Reveals Uptick in Global Gas Flaring. Accessed 7th July, 2018. http://www.worldbank.org/en/news/press-release/2016/12/12/new-data-reveals-uptick-in-global-gas-flaring

Zhao Y & Zhao C 2012. Concentration and distribution analysis of heavy metals in total suspended particulates along Shanghai- Nanjing Expressway. *Procedia Environmental Science*, 13: 1405-1411.