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Environmental Sustainability: Assessing the Impact of Air Pollutants Due to Gas Flaring - Qua Iboe Estuary Case

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Abstract This study presents physicochemical characteristics (NO_3^-, SO_4^{2-}, CO_3^{2-}, suspended particulate matter, CO and pH) in air from Qua Iboe Estuary investigated as a result of the gas flare site located in Mkpanak, Ibeno in coastal area of Akwa Ibom State, Nigeria. Air and rainwater samples were collected during the dry and wet seasons in (2011-2012) and analyzed for the above physicochemical species using standard methods. Mean and standard deviation were used to assess the impact of these species in the region. Results obtained revealed that the mean concentrations of NO_3^- (44.77mg/m^3 and 19.95 mg/m^3) and SO_4^{2-} (7.54 mg/m^3 and 4.53 mg/m^3) in dry and wet seasons were very low and were within the safety limits, suggesting minimal or no adverse effects on the environment. However, the mean concentrations of CO_3^{2-}(2777.46 mg/m^3 and 2859.69 mg/m^3, CO(60.29 mg/m^3 and 32.65 mg/m^3) and pH (5.98 and 6.68) in dry and wet seasons respectively, were higher than the acceptable ambient air limits specified by the Federal Ministry of Environment (FMEnv) and Department of Petroleum Resources (DPR), Nigeria. Based on these findings, it can be concluded that within the studied region, the activity of constant gas flaring is one of the major sources of high concentration of these physicochemical species, with significant implications for the sustainability of the environment and life forms in this area. Recommendations are made to address these issues as best practices are presented.

Keywords: *air pollutants, environmental sustainability, gas flare, pollution, qua Iboe estuary*

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1. Introduction

Environment, the totality of man's physical surroundings; air, land and water, where human beings, animals or plants live are a dynamic system. The health and well-being of everything on earth as well as the economy of nations depend on it. These environmental components have been adversely affected by man's continuous interactions such that there has been a growing need to address the challenges posed by these factors and activities that instigate un-sustainability [17]. Indeed, Wilkinson, et al., [29] reported that human activities were particularly the cause of the disruption of the biosphere life support systems. These include biodiversity loss, changes in the composition of the atmosphere (air pollution), over-exploitation of aquifers, growing demand for energy or exploitation of fossil energy resources and increasing problems of waste disposal. This list also contains incidences of flooding, tsunamis, erosion and devastating effects all over the world[13].

2. Environmental Sustainability

Sustainability is based on the premise that social, economic and environmental systems constantly interact with people and their communities. These systems must be balance if they are to continue to function to the benefit of its inhabitants, now and in the future. A universally accepted definition of sustainable development expresses the development that meets the needs of the present without compromising the ability of future generations satisfying their own needs [23,28]. However, it explains further that sustainability is improving the quality of human life while living within the carrying capacity of supporting the ecosystems [20].

Environmental sustainability arose out of the growing recognition that humans are afflicting many of the earth's critical resources, not only locally, but, also at a global scale with potential effects on human as well as ecological health [18,26]. Adedeji and Eziyi [1] identified several problems instigating against sustainability of the environment in Nigeria and subdivided them into pollution, deforestation, global warming and slum development.

In Nigeria, oil companies engage in gas flaring, as a 24 hours-a-day, 365 days-a-year practice. Some of these flares have burned without cessation for more than 50 years [3]. Nigeria is blessed with abundant natural resources with oil and gas as Nigeria's major economic determinant and mainstay. Nigeria produces more natural gas than it uses, this is because most of the natural gas produced is associated gas (related with crude oil) encountered in the oil well during oil production. This gas cannot be avoided, thus it is largely flared. Nigeria flares 17.2 billion m^3 of natural gas per year in conjunction with the exploration of crude oil in the Niger Delta [3,6].

This high level of gas flaring is approximately one quarter of the current power consumption of the African continent. Even though Nigerian has grown to be fairly dependent on oil and it has become the center of current industrial development and economic activities, how oil exploration and exploitation processes create environmental, health, and social problems in local communities near oil producing fields have been rarely considered.

The burning process associated with the flaring is called combustion and is the rapid oxidation or burning of gas with simultaneous evolution of heat and light. Gas flaring emits carbon (IV) oxide (CO_2), carbon (II) oxide (CO), methane (CH_4), hydrogen sulphide (H_2S), nitrogen (IV) oxide (NO_2), nitrogen (II) oxide (NO), nitrogen (I) oxide (N_2O), sulphur (IV) oxide (SO_2), sulphur (VI) oxide (SO_3), soot, smoke and heat.

2.1. Environmental Issues

The products released by flaring or combustion of natural gas have the potential of altering the natural state of the environment, leading to production of greenhouse gases (GHG), regional climate change and eventually leads to global warming. Drilling mud and oil sometimes find their way to the streams, surface waters and land thereby making them unfit for consumption or habitable by man and animal.

Acid rains have been linked to the activities of gas flaring, the primary cause being the emission of sulphur (IV) oxide and nitrogen (II) oxide which combine with atmospheric moisture to form H_2SO_4 and nitric acid respectively. The effects of acid rain on acceleration of decay of building materials like corrugated roofs, acidification of streams and rivers however causes damage to vegetation. SO_2 and NO contribute to visibility degradation and harm to public health [12,16].

Agricultural activities are also affected as gas flaring contributes to atmospheric contaminants with particulate matter, hydrocarbons and ash, photochemical oxidants as well as hydrogen sulphide, this development promotes acidified soil, hence depleting soil nutrients. A Study by Kindzierski, [14], indicates that there is no vegetation in the areas around the flare partly due to tremendous heat produced and acidic nature of soil pH. [6,14,21] further maintained that effect of temperature on crops include stunted growth, scotched plants, depressed flowering, fruiting, withered young plants and concluded that soils of flare areas are fast losing their fertility and capacity for sustainable agriculture.

Carbon (IV) oxides for example can upset natural CO_2 cycle and also implicated in global warming. Carbon (II) oxide is extremely poisonous, because of its great affinity for haemoglobin in red blood cells thus preventing the carriage of oxygen by haemoglobin to essential parts of the body cells [3]. Excessive heat released during flaring can lead to skin discoloration, cancer, deformities in children, haematologcal effects, increased enzymatic activities resulting in death and decreasing breeding potentials of animals [21]. Several previous studies in this area have documented information about hazard experiences as a consequence of gas flaring impact on Niger Delta environment. The purpose of this study is to assess the impact of air pollutants in Qua Iboe Estuary due to gas flaring in the area.

3. Study Area

Qua Iboe river estuary forms the pivot of this study, the river flows through many towns and villages in Akwa Ibom State within the Niger Delta region of Nigeria. This estuary has many tributaries that pass through many towns and villages in the following Local Government Areas: Ikot Abasi, ONNA, Eket, Ibeno, Esit Eket, and Mbo. This estuary is located within latitude 4^0 30^0N – 4^0 45^0N and longitude 7^0 30^0E-8^0 45^0E [9,24]. Three sampling sites: Ibeno (location of flaring sites), the spill effect areas of Esit Eket and Eket respectively, where other oil exploration activities are ongoing were considered. The flare burns continuously emitting high concentrations of soot and smoke an indication of incomplete combustion as shown in Figure 1. Figure 2 shows the map of study region and the locations of sampling sites.

Figure 1. A Typical Gas Flare Site, ExxonMobil Farm (Mkpanak, Ibeno)

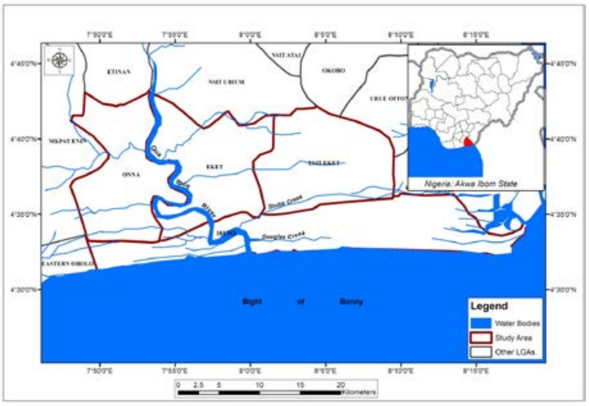

Figure 2. Location of Study (Qua Iboe estuary)

4. Methodology of Study

This study adopts several methodologies for the achievable results. Air samples were collected from the study sites during the peak of dry season (December 2011 – March 2012) and wet season (April –July 2012) using dust samplers, automated instruments that trap the air and measure physicochemical parameter of choice and their concentrations read off the screen. The following physiochemical parameters were considered because they are considered as a good impact indicators of the state of the ambient air and the surrounding environment: *Suspended particulate matter (SPM)*: particulate monitor (Haz-dust SKC Model) was used to obtain values of concentrations of SPM in air in-situ.

Sulphate (SO_4^{2-}) *in air:* sulphur dioxide gas monitor (Gasman Model 19831H) was used to take values and it measures sulphate in the range of (0-50ppm).

Carbon Monoxide (CO) in air: carbon monoxide gas monitor (Gasman Model 19252H) was applied to obtain values and it measures values in the range of (0-500ppm).

Nitrate (NO_3^-) *in air:* nitrogen dioxide gas monitor (Gasman Model 19648H) was adopted and read values in the range of (0-50ppm). In addition, *carbonate* (CO_3^{2-}) gas monitor (Gasmas Model 19335) was used to measure the concentration of carbonate in the air and measures in the range of (0-5000) ppm. All values were obtained in-situ during this investigation.

Acid rain is linked with activities of gas flaring, therefore, rainwater samples were collected to determine the pH levels and ascertain the atmospheric pollution of the estuary. Using [2,25] methods, rainwater samples were collected with clean plastic basins and two litre plastic bottles because they have low metallic content and non-polar surface [2]. All basins and bottles were thoroughly washed and rinsed with the rainwater collected; this was to ensure no foreign soluble substances originally in the container contaminate the samples. The basins were kept on stands above ground levels in the open outside, devoid of interference from trees and roof top. The water collected in the basins were immediately transferred into the polyethene bottles, sealed, labeled and conveyed to the laboratory for analysis. Benchtop Jenway pH-meter model 3071 was used to measure the pH of the rainwater and values were read off the screen. Eqns. (1) and (2) were applied to determine the mean and standard deviation of the measured species.

In Eqn. (1), the mean was analysed thus;

$$X = \frac{\sum x}{n} \quad (1)$$

Where; $\sum$ = The summation of sample data

n = Total number of achievable data

x = Value of each observation

X = Mean.

Eqn. (2), the standard deviation was computed using this mathematical representation;

$$S = \sqrt{\frac{\sum(x-X)^2}{n}} \quad (2)$$

Where, $\sum$ = The summation of sample data

n = Sample size

x= Observation

X = Mean

S = Standard deviation

5. Results and Discussion

Values of parameters obtained from physicochemical analyses conducted on air and rainwater samples from Ibeno, Esit Eket and Eket for the period of (December 2011 – July, 2012, Table 1), were computed for dry and wet seasons. Mean concentrations and their standard deviations are presented in Table 2 and Table 3. In this investigation, mean values were compared with guidelines of Nigerian ambient air quality standard [7,11] as shown in Table 4.

Table 1. Samples Collected and Duration

S/N	Location	Period of sample collection	Parameters					
			NO_3^-	SO_4^{2-}	CO_3^{2-}	SPM	CO	pH
Dry Season Values Obtained								
1	Eket	December 2011	42.002	8.711	2870.399	8.875	50.031	5.90
		January 2012	44.240	8.958	2884.860	9.439	44.058	6.22
		February 2012	42.041	8.856	2783.915	7.104	41.058	5.70
		March 2012	39.757	8.955	2846.346	4.902	42.104	6.10
2.	Ibeno	December 2011	44.655	7.379	3776.280	9.404	76.761	4.90
		January 2012	47.026	7.958	3521.915	11.052	90.858	5.80
		February 2012	46.542	7.332	3980.561	9.426	89.675	6.20
		March 2012	46.079	6.611	3626.244	8.998	69.060	5.90
3.	Esit Eket	December 2011	42.655	6.590	2061.435	8.404	59.705	6.40
		January 2012	53.026	6.713	1825.561	7.998	50.673	5.90
		February 2012	48.542	5.996	1389.280	9.785	49.997	6.50
		March 2012	40.647	6.433	1762.764	6.773	58.627	6.28
Wet Season Values Obtained								
4	Eket	April 2012	23.856	6.257	2384.688	6.104	28.646	6.88
		May 2012	20.908	4.982	1684.813	5.773	32.014	6.86
		June 2012	19.024	2.591	1829.304	7.272	29.780	6.74
		July 2012	13.172	6.090	1652.835	8.251	33.260	6.76
5	Ibeno	April 2012	20.308	2.998	4006.186	8.537	31.322	6.60
		May 2012	22.996	3.507	3812.240	8.089	34.721	6.49
		June 2012	21.856	3.784	3701.00	7.946	32.238	6.56
		July 2012	16.000	3.751	3277.668	7.788	30.679	6.55
.								
6.	Esit Eket	April 2012	23.304	8.752	2769.293	5.973	43.675	6.59
		May 2012	20.218	3.833	2991.870	6.874	34.889	6.69
		June 2012	20.690	3.810	3011.451	8.219	30.942	6.69
		July 2012	17.028	3.445	3194.868	8.014	29.374	6.74

Table 2. Mean Concentrations±S.D. of Physicochemical Variables (mg/m^3) in Air during Dry Season (December-March 2011-2012).

Parameter	Sampling Sites			Mean	* SD
	Eket	Ibeno	Esit Eket		
NO_3^-	42.01	46.08	46. 22	44.77	± 1.95
SO_4^{2-}	8.87	7.32	6.43	7.54	± 1.01
CO_3^{2-}	2846.38	3726.25	1759.76	2777.46	± 804.29
SPM	7.58	9.72	8.24	8.41	± 0.90
CO	44.38	81.75	54.75	60.29	± 15.75
pH	5.98	5.70	6.27	5.98	± 0.23

*SD - Standard deviation

Table 3. Mean concentrations ± SD of Physicochemical Variables (mg/m^3) in Air during Wet Season (April – July 2012)

Parameter	Sampling Sites			Mean	*SD
	Eket	Ibeno	Esit Eket		
NO_3^-	19.24	20.29	20.31	19.95	± 0.50
SO_4^{2-}	5.10	3.519	4.96	4.53	± 0.71
CO_3^{2-}	1887.91	3699.29	2991.87	2859.69	± 745.77
SPM	6.85	8.09	7.27	7.40	± 0.52
CO	30.90	32.24	34.72	32.65	± 1.58
pH	6.81	6.55	6.69	6.68	± 0.11

*SD - Standard deviation.

Table 4. Comparative Analysis of Physicochemical Variables with Ambient Air Quality Standards

Parameter	Results		FMEnv, [11], DPR [7] Standards
	Dry Season	Wet Season	
NO_3^-	44.77	19.95	350-1000
SO_4^{2-}	7. 54	4.53	30-100
CO_3^{2-}	2777.46	2859.69	50-250
SPM	8.41	7.40	1.15
CO	60.29	32.65	10
pH	5.98	6.68	6.5-8.5

Our results show, the mean nitrate concentrations in the studied samples were 44.77 ± 1.95mg/m^3 and 19.95 ± 0.50 mg/m^3 for dry and wet seasons respectively. The mean sulphate values for both seasons were correspondingly 7.54mg/m^3±1.01 and 4.53 ± 0.71 mg/m^3. NO_3^- and SO_4^{2-} levels are below the limits of ambient air quality, thus posing no threat to the environment. Carbonate values obtained in the samples analysed showed significant seasonal variation deduced from dry wet seasons. However, mean dry season values of 2777.46 ± 804.29mg/m^3 of CO_3^- was lower than wet season values of 2859.69 ±745.77mg/m^3 this could be attributed to dispersion of pollutant by wind. The values were high when compared to maximum allowable CO_3^- in ambient air. These high values are as a result of continuous gas flare, burning of fuel and dust generated due to less rainfall despite being wet seasons. These are indications of pollution in the area and agree with similar studies by [15,22], thereby posing a threat to environment sustainability.

In addition, Carbon (II) oxide values obtained showed significant seasonal variation deduced from 60.29 ± 15.75 mg/m^3 values for dry season and 32.65 ±1.58 mg/m^3 for wet season. These high mean values are attributed to incomplete combustion of the gas flared [10], biomass combustion and heavy traffic and indication of pollution of this area by the presence of CO emission. This finding agrees with earlier studies by [4,27].

From these results, mean pH values of the samples were 5.98±0.23 and 6.68±0.11 for dry and wet seasons respectively. This shows the rainwater under study is acidic as the dry season value was outside [7,11] drinking water limit of (6.5 – 8.5). Acidity may have resulted from continuous presence of oxides of carbon, which enters the atmosphere from gas flare alongside other substances such as oxides of sulphur and nitrogen that are converted to sulphur, nitric and carbonic acids. Statistically, the mean values showed a significant seasonal variation. The result agrees with earlier studies conducted by [8,19,21] that the pH of rain water in gas flared communities and environs are acidic.

Suspended particulate matter in air is as a result of a wide range of finely divided solids that may be dispersed into air from combustion process, industrial activities or natural sources. The mean concentrations of SPM in air were 8.41±0.90mg/m^3 and 7.40±0.52mg/m^3 for both dry and wet seasons indicated higher values than [7,11] standards. This is attributed to soot and smoke from the stacks of the gas flare and therefore poses a problem to the health of the people in this area and also to environmental sustainability. This finding agrees with highly significant values recorded by Tawari and Abowei, [22] in their studies.

6. Conclusion and Recommendations

The difficulties faced by local communities from gas flares are a sufficient justification for ending gas flaring practice. Technologically, it is possible to stop gas flaring either through re-injection or utilization. Considering capital intensity, government and the companies involved should look beyond the amount of investment input, but focus on the implications to humans, living things and the environment. The first legislation that prohibited gas flaring was in 1984, up till now, the draft of Petroleum Industry Bill (PIB) which stipulates that natural gas should not be flared or vented after 31st December, 2012 in any oil and gas operation, block or field onshore or offshore is yet to be passed into law.

Legislative backing and government bureaucracy still remains a stumbling block in this case. Government should therefore as a matter of urgency, make stringent laws and take drastic actions against defaulting companies not just by payment of fines. Penalty of fines for defaulting companies should be so exorbitant to deter oil/gas exploration companies from flaring activities. Furthermore, rather than gas flaring in this case, it will be more beneficial and eco-friendly should it be processed into cooking/domestic gas as a recyclable measure for economic use. There is no "away" to which waste or unwanted products are disposed, a better solution to pollution is prevention. Monitoring air pollutants within Qua Iboe Estuary has shown that the environment poses a threat to safety of man, and ecosystem sustained by this environment generally.

With mean values of SPM, CO, CO_3^- and pH exceeding limits specified for ambient air quality, it could therefore be concluded that there is a serious environmental issues within the estuary and its environs. Overall, the Federal Ministry of Environment should pursue the zero-flare down programme to a logical conclusion.

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