



Air Pollution Assessment of a Gas Flare Site in the Niger Delta Region

Chioma Olivia Ehumadu^{1*}, Uyigue Lucky¹
and Ndekwu Benneth Onyedikachukwu²

¹Department of Civil and Environmental Engineering, University of Port Harcourt, River State, Nigeria.

²Department of Civil Engineering, University of Nigeria, Nsukka, Enugu State, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Author UL designed the study and wrote the protocol. Author COE performed the statistical analysis and managed the analyses of the study. Author NBO wrote the first draft of the manuscript and managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JERR/2021/v20i817366

Editor(s):

(1) Dr. P. Elangovan, SRM TRP Engineering College, India.

Reviewers:

(1) Swapnila Roy, K. K. University, India.

(2) Carlos Deliz, University Ana G. Mendez and University of Puerto Rico, Puerto Rico.

Complete Peer review History: <http://www.sdiarticle4.com/review-history/69064>

Received 12 April 2021

Accepted 18 June 2021

Published 26 June 2021

Original Research Article

ABSTRACT

Aim: The aim of this research was to investigate the level of air pollutants generated from a gas flaring plant in Ogbogu and Ebocha communities of Rivers State, Port Harcourt, Nigeria.

Study design: Seven monitoring stations were selected for Air quality monitoring, which involved measurement of basic air quality index and meteorological parameters using standard meteorological Equipment. Monitoring locations were selected with respect to the prevailing wind direction from the flare point. The following measurements were conducted;

- Gas emission: CO, SO₂, NO₂, VOC, CH₄, H₂S, NH₃
- Meteorological: Humidity, Wind Velocity, Wind direction, Atmospheric Pressure, Heat Radiation and Smoke density.

Place and duration of study: This study was carried out in Ogba/Egbema/Ndoni Local Government Area of Rivers State. This area was chosen for this study because of the high volume of petroleum activities. Oil and gas processing, production, transportation and utilization for power generation occur daily in the area resulting in numerous cases of environmental degradation and pollution.

Methodology: A multigas Detector MSA Orion is used to monitor the different gases at 20m, 50m, 100m, 500m, and 700m. A Krestel Exttech model 45112 mutli-parameter air quality equipment is

used to determine the direction of wind flow and speed at a particular location.

Results: The gases flared are in decreasing order of NO_x , SO_x , CO , VOC , SMP at increasing distance. This implies that the health of the people in the study area is affected negatively especially those living very close at 20- 100m distance to the flare site since the gases are occurring at levels higher towards the allowable limits of FEPA. The quantity of carbon emitted by these flares is about 2,525,000.00 tons of carbon per day. These values portray a bad omen for the affected communities. This study recommends that gas flaring should be seen as violent action against the people and that the flared gas should be channeled to meeting the ever increasing demand for energy in the industrial sector of the economy.

Conclusion: It is safe to conclude that gas flaring not only produces excessive heat which alters the temperature of the environment, but also causes gaseous pollutants to be present in the environment and this may have adverse effects on the inhabitants and thus on the socio-economic activities of Ebocha community. The temperature of the environment returns to normal at about 450m away from the flare stack. Residential buildings should therefore be located and agricultural activities should be encouraged within this range of distance.

Keywords: Gas flaring; air quality; gas emission; meteorological data.

1. INTRODUCTION

Gas flaring according to the World Bank [1] is “a wasteful emission of greenhouse gases that causes global warming”. It is the process of burning unutilized associated gases (a blend of hydrocarbons) into the atmosphere [1] during oil and gas exploration activities. Associated gas, found mixed together with oil in oil deposit needs to be separated from it before refining. This is achieved by three basic ways: harvesting the gas for domestic or commercial purposes, reinjection into the ground for future harvesting and burning of the gas (gas flaring) [2,3].

Nigeria, which is the sixth largest oil producer in the world, the seventh largest gas reserves in the world and the largest in Africa, is second only to Russia in gas flaring [4]. She has a proven gas reserve of over 4 trillion m^3 [24 billion barrels of oil equivalent, about 1.51×10^{12} J (Tera Joules) thermal equivalent] of which 50–50% is for both associated gas (AG) and non-associated gas (NAG) [5]. The World Bank reported that in 2004, volume of gas flared in Nigeria was equivalent to one-sixth of total gas flared in the world [1,6] also reported that the estimated amount of gas flared in Nigeria in 2008 was 15.1BCM.

In Nigeria, gas flaring started since the discovery of crude oil in the late 1950s and has been ongoing until date. This flaring activities takes place in the Niger Delta region of Nigeria, the largest mangrove swamp in Africa and the second largest delta in the world [7,2] with a total of 131 gas flaring sites (National Space Research and Development Agency [NASRDA], [8]. Fig. 1 shows the gas flaring sites in the Niger Delta region of Nigeria.

A report by Abdulkareem et al, [9] stated that an estimated amount of 56.6 million m^3 of AG is flared daily in Nigeria. Not all the AG produced in Nigeria is flared. The gas is reused as fuel, sold to third parties, converted to Liquefied Natural Gas (LNG) or re-injected to enhance oil recovery [10]. Although there has been a remarkable decline in percentage of volume of gas flared from over 95% in the 1960s to approximately 24% in 2010 (see Fig. 2), its economic loss, environmental degradation and health hazard cannot be ignored.

The World Bank estimated that Nigeria gas flares contribute about 70 million metric tons of carbon dioxide emissions a year (10 percent of global CO_2). It also releases about 12 million tons of methane (CH_4), which is said to have higher warming capabilities than CO [1,11].

Data for Nigeria's air quality status puts the population exposed to air pollution at $\text{PM}_{2.5}$ levels, and exceeding WHO guidelines, at 94%. This number is above the 72% Sub-Saharan Africa average [12,13].

Several studies have not only emphasized the poor air quality in the Niger Delta, including Port Harcourt, but have also highlighted on the high pollutant generation far above national and international regulatory-recommended levels of ambient air pollutants [14-16].

In the midst of all these unfriendly and degenerating environmental issues the poor are most disproportionately affected [17].

The aim of this study was to estimate the rate of pollutants build-up in air as a results of

uncontrolled Gas flaring and power plant emissions on the environment within the Niger Delta region and then provide adequate approach to address these practices.

2. MATERIALS AND METHODS

2.1 Field Sampling Equipment

Sampling equipment, forms and data acquisition material used during the field work includes:

- GPS for coordinate mapping & Camera
- Hand towel, cutlass and rubber hand gloves
- Field sampling sheet/book
- Distilled water and brush to decontaminate the sampling equipment.
- Gas Detector for SO₄, NO₄, CO, H₂S, NH₄, Methane.

2.2 Sample Parameters Measurement

2.2.1 Heat Radiation Measurement

Heat emitted from the stack is been measured at 200m, 500m, 1000m, 5000m, 7000m away from the flare. Flaring is a combustion process which

has been and remains the traditional methods for the safe disposal of large quantities of unwanted flammable gases and vapors in the Oil Industry. Infra-red thermometer was used to monitor the fraction of heat radiated from flames and ground level. The heat radiated from the flames was calculated using Stefan-Boltzmann equation.

The energy radiated by a blackbody radiator per second per unit area is proportional to the fourth power of the absolute temperature and is given by;

$$\frac{p}{a} = e\sigma T^4 \text{ J/m}^2\text{S}$$

where;

P is the total power radiated (energy per unit time) per unit surface area

A is the surface area

e is the emissivity. For most objects this is taken to be 1.

σ is the Stefan-Boltzmann constant.

T is the temperature of the object expressed in degrees Kelvin

$$\sigma = 5.6703 \times 10^{-8} \text{ watt/m}^2\text{K}^4$$

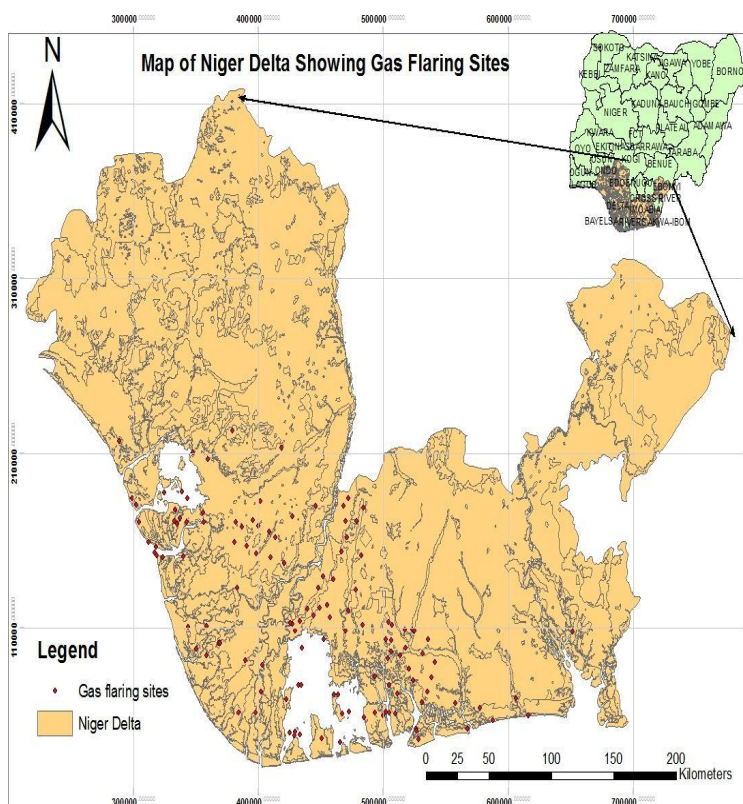


Fig. 1. Map of Niger Delta showing Gas flaring sites [8]

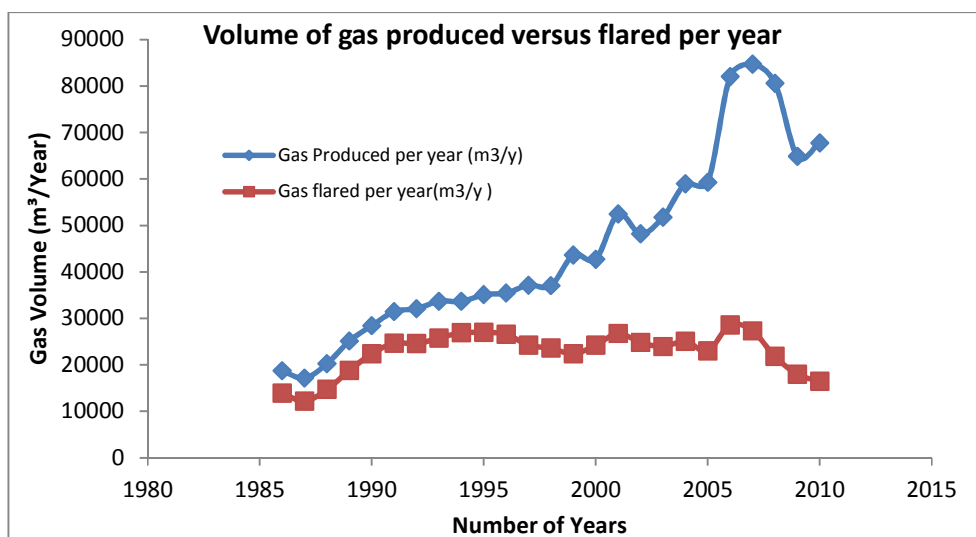


Fig. 2. Declining trend in the volume of gas flared in Nigeria (National Geophysical Data Centre, NGDC)

2.2.2 Gas Measurement: CO, NO_x, SO_x, VOC, H₂S, NH₄ and SPM

A preliminary measurement was conducted in comparison with the DPR standard prior to monitoring to determine the effect or impact of gas venting within the proposed locations. A multi-gas Detector MSA Orion is used to monitor the different gases at 20m, 50m, 100m, 500m, and 700m.

2.2.3 Measurement for Wind Direction Wind Speed

A Krestel Extech model 45112 multi-parameter air quality equipment is used to determine the direction of wind flow and speed at a particular location.

2.2.4 Measurement of Noise Levels

Noise levels at each point were measured with a pre-calibrated digital readout noise meter. The sensor of the noise meter was directed towards the source of noise and the average readings over a period of two minutes were taken to be the Noise-level at each point. The noise levels were measured in decibels (dB).

2.3 Collection of Data

Five sampling points were selected within the study area at different points; 200m, 500m, 1000m, 5000m and 7000m with two control stations away from the area of concentration

(AOC). Each of the selected point is mapped using a Global Positioning System (GPS) at various proximities from the flare locations were taken and measurements and experimentations meticulously carried out on Air Quality.

2.3.1 Air Quality Monitoring

Seven monitoring stations were selected for the Air quality monitoring, which involves measurement of basic air quality index and meteorological parameters using standard meteorological Equipment. The following measurements were conducted;

- Gas emission: CO, SO₂, NO₂, VOC, CH₄, H₂S, NH₃
- Meteorological: Humidity, Wind Velocity, Wind direction, Atmospheric Pressure, Heat Radiation and Smoke density.

3. RESULTS AND DISCUSSION

3.1 Assessment of Air Quality Parameters at Strategic Distances for the Selected Communities

Analyses of the gas flaring activities on the two communities was done jointly to capture the effect of cross wind contamination, considering the fact that Ogbogu and Ebocha gas were still being flared and the two flaring sites were at very close distance apart. Thus, the analysis in this report considers the effect of pollution on the

environment of these two communities to be approximately the same. The result of the preliminary air quality monitoring carried out to determine the environmental conditions of these locations is represented in Tables 1 and 2.

A cumulative summary of the measured air quality parameters at varied distances of Ogbogu and Ebocha gas flaring site is as shown in Table 3.

3.3.1 Air Quality Parameter Distribution

Gases flared are in decreasing order of $NO_x > SO_x > CO > VOC > SMP$ at increasing distance. This implies that the health of people in the study area is affected negatively especially those living at a distance of 20- 100m to the flare site. This is as a result of increased levels of flared gases higher than allowable limits. If SO_x for example is properly harnessed, it is a food preservative, fumigant, bleaching agent in the manufacture of sulfuric acid while NO_x is a poisonous brown gas not safe for both crops and human health.

SO_2 being of major concern recorded annual values within the DPR limit of $250\mu g/m^3$ at the different sampled locations. The highest annual average SPM value of $8.12\mu g/m^3$ was recorded 20m from flare point. The trend for Suspended Particulate Matter followed a decreasing order as the distance from flare point increased with the season. Nkwocha and Egejuru [18] 2008 had

reported on estimates for the Long Range Transport of Air Pollutants.

Recorded data also showed that the level of CO measured from the distances close to flare point was far above the recommended standard of DPR. The measured distances of 20m, 35m, 50m and 75m showed average CO values of $18.80\mu g/m^3$, $19.08\mu g/m^3$, $10.47\mu g/m^3$ and $11.40\mu g/m^3$ respectively. CO measured values decreased as the distance from the point of flare increased.

Details of other measured gases and particulates are as shown in Fig. 3.

The effect of the flare on atmospheric temperature was measured to a radius of 700m at $29.80^\circ C$, which extended far off the flare immediate site. Beyond this point, the atmospheric temperature was similar to ambient conditions as shown in Fig. 4. The average temperature values range from $29.80^\circ C$ at 700m from flare site to $42.8^\circ C$ at 20m to the flare point.

A comparative plot of temperature, noise level and humidity at the different measured locations is as shown in Fig. 5.

More so, the smoke density measures for the flare showed 100% compliance and were below the DPR Regulatory level of two (2) Ringlemann. However, smokeless emissions have been reported not to have any effect on sulphur dioxide emissions [19]. A plot of measured smoke density and wind speed at the sampled locations is as shown in Fig. 6.

Table 1. Preliminary Air Quality Monitoring for Gas Measurement from Ogbogu Gas Plant and Ebocha Gas Plant

S/N	Distance (m)	Temp (°C)	Gases Flare ($\mu g/m^3$)				
			CO	NO_x	SO_x	VOC, Lev	SPM($\mu g/m^3 \times 10^1$)
1	20	44.50	16.41	40.33	21.66	7.11	7.60
2	35	42.2- 44.0	10.30	37.10	19.43	5.09	5.17
3	45	39.0- 41.2	8.70	36.86	21.90	4.81	5.46
4	50	29.2 – 38.9	7.30	41.90	29.16	4.10	3.94
5	65	29.10	5.11	33.67	20.33	2.09	2.11
6	75	29.9-30.4	5.11	32.44	20.85	2.14	2.05
7	100	28.30	4.76	28.30	16.46	1.96	1.50
8	125	28.0- 29.0	2.06	18.11	10.30	1.50	1.01
9	150	29.0	1.02	0.05	0	0	0.051
10	300	29.0 – 30.0	0	0	0	0	<0.051- 0.030
11	500	30.0	0	0	0	0	0.0251
12	700	30.0 – 31.0	0	0	0	0	0.0015

DPR Standard: Temp= NA, $CO=10\mu g/m^3$, $SO_x = 100\mu g/m^3$, $NO_x= 150\mu g/m^3$, VOC = NA, SPM = 60-90 $\mu g/m^3$
 Key: SO_x = Sulphur Oxide, NO_x = Nitrogen Oxides, VOC = Volatile Compounds, SPM = Small Particulate Matter,
 NA= Not Available

Table 2. Preliminary Air Quality Monitoring for Meteorological Measurement from Ogbogu GP and Ebocha Gas Plant

S/N	Distance (m)	Temp, (°C)	Meteorological Measurement				
			Noise Level, (dBA)	Heat Radiation (w/m ²)	Smoke Density (Ringlemann)	Humidity (%)	Wind Velocity (m/s)
1	20	44.50	96.70	4518.69	2.0	58.70	0.90
2	35	42.2- 44.0	93.80	4162.50	2.0	57.30	0.80
3	45	39.0- 41.2	91.70	3960.44	2.0	55.40	1.10
4	50	29.2 – 38.9	78.40	2910.06	2.0	59.80	1.30
5	65	29.10	83.90	2994.63	2.0	60.30	1.20
6	75	29.9-30.4	86.20	2720.31	1.0	67.80	1.40
7	100	28.30	74.60	1351.11	1.0	65.40	0.70
8	125	28.0- 29.0	72.00	1180.72	1.0	68.20	0.90
9	150	29.0	71.50	541.90	1.0	59.40	1.40
10	300	29.0 – 30.0	60.70	490.17	0	58.60	1.10
11	500	30.0	67.60	371.59	0	60.20	0.90
12	700	30.0 – 31.0	62.00	251.80	0	62.70	0.80

Table 3. Summarized Air Quality and Meteorological Data from the different Points of Ogbogu and Ebocha Gas Plant

Sampling Site:		Air quality and meteorological quality for the study area (Ogbogu & Ebocha Gas Plant) Port Harcourt.									
Sampling Point:		20m	35m	50m	75m	100m	500m	700m	DP	FM	
GPS:		N05 ⁰	N05 ⁰	N05 ⁰	N05 ⁰	N05 ⁰	N05 ⁰	N05 ⁰	R	E	
		21'	21'	19'	21'	21'	21'	20'	Limi	Limi	
		09.6"	10.3	10.3"	11.2"	50.1"	54.6"	32.0"	ts	ts	
		E006 ⁰	1"	E006	E006	E006	E006	E006			
		40'	E00	⁰ 36'	⁰ 36'	⁰ 36'	⁰ 36'	⁰ 36'			
		27.7"	6 ⁰	27.4"	24.2"	30.4"	39.2"	40.7"			
			36'								
			22.1'								
S/ N	Parameters	Equipment or Method									
1	SO ₂ (µg/m ³)	Gas Detector	26.90	21.6	27.90	23.12	17.07	<0.01	<0.01	100-150	26-260
2	NO ₂ (µg/m ³)	Gas Detector	42.89	39.0	32.51	33.07	25.10	0.012	<0.01	150	75-113
3	H ₂ S (µg/m ³)	Gas Detector	19.48	20.7	17.03	11.08	14.55	0.21	<0.01	--	
4	Carbon Monoxide CO (µg/m ³)	Gas Detector	18.80	19.0	10.47	11.40	6.12	1.01	<0.01	10	11.4-22.8
5	THC/VOC (µg/m ³)	Gas Detector	8.03	7.54	8.02	3.17	1.06	0.08	<0.01	-	160
6	CH ₄ (µg/m ³)	Gas Detector	45.90	38.1	40.98	27.09	22.76	1.74	<0.01	-	
7	Ambient Temperature (°C)	Thermometer	42.80	40.1	35.80	30.10	31.60	29.80	31.30	-	-
8	Particulates	Laser part.	8.12	4.09	4.74	1.96	1.18	<0.01	<0.01	60-90	250-

Sampling Site:			Air quality and meteorological quality for the study area (Ogbogu & Ebocha Gas Plant) Port Harcourt.								
9	($\mu\text{g}/\text{m}^3$) Relative Humidity (%)	Count Humidity meter	61.5	64.5	61.8	64.90	63.20	62.10	62.30	-	600
10	Smoke Density (Ringleman)	BS 2742:1969	2.0	2.0	2.0	1.0	0	0	0	2	-
11	Atmospheric Pressure (Kpa)	Digital Barometer	100.86	100.87	100.86	100.86	100.90	100.87	100.87		
12	Noise Level (dBA)	Sound Meter	98.60	92.80	87.50	90.10	78.30	65.50	68.10	80-100	90
13	Heat Radiation (W/m ²)	Radiometer	4710.83	4033.72	3061.09	2458.21	1369.51	582.79	173.88	6310	-
14	Wind Speed (m/s)	Anemometer	0.60	1.50	1.20	0.70	0.80	1.10	1.10	-	-
15	Wind Direction	Anemometer	NE	NE	NE	NE	NE	NW	NW	-	-

Heat radiation showed was 100% compliance with the DPR limit. The highest heat radiation levels monitored at the different locations during the period were far below the DPR limit. The average Heat Radiation values ranged from 173.88W/m² at 700m radial locations to

4711W/m² at 20m locations near the flare point. The heat radiated from the flare is a factor of air pollution, which could have adverse effects on both crops and animals living around the area (20m -100m). A plot of heat radiation distribution for the measured locations is as shown in Fig. 7.

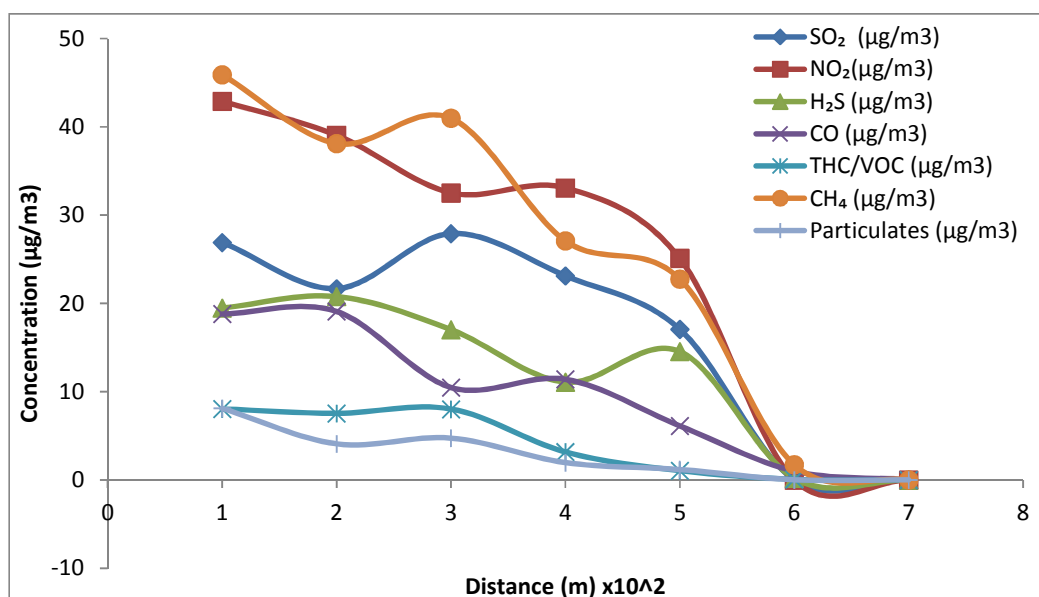


Fig. 3. Flared gas concentration at varying distances

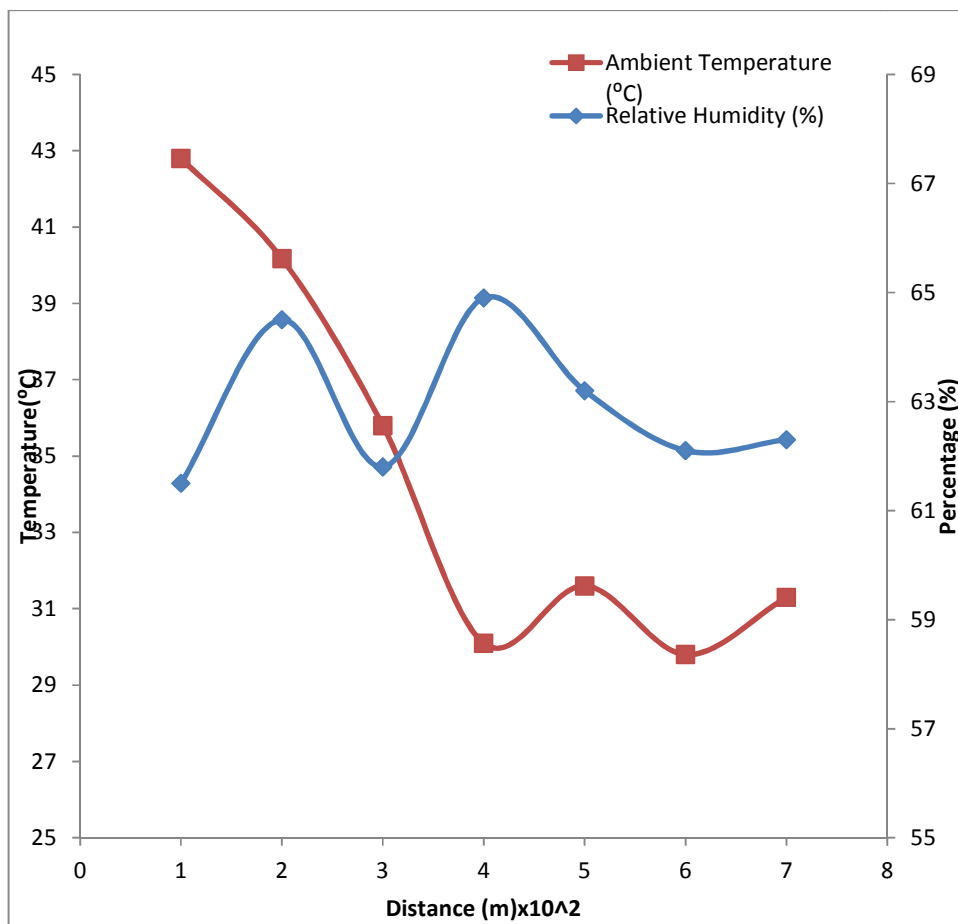


Fig. 4. Temperature and Relative Humidity measured at varying distance

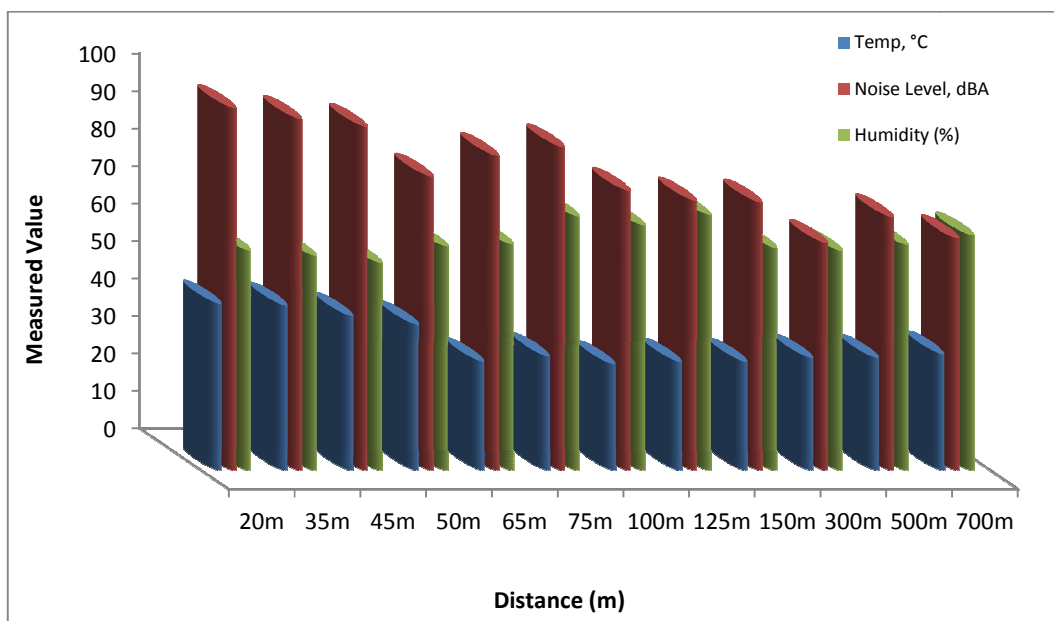


Fig. 5. Bar Chart plot of measured Temperature, Noise level and Humidity at Varying distances

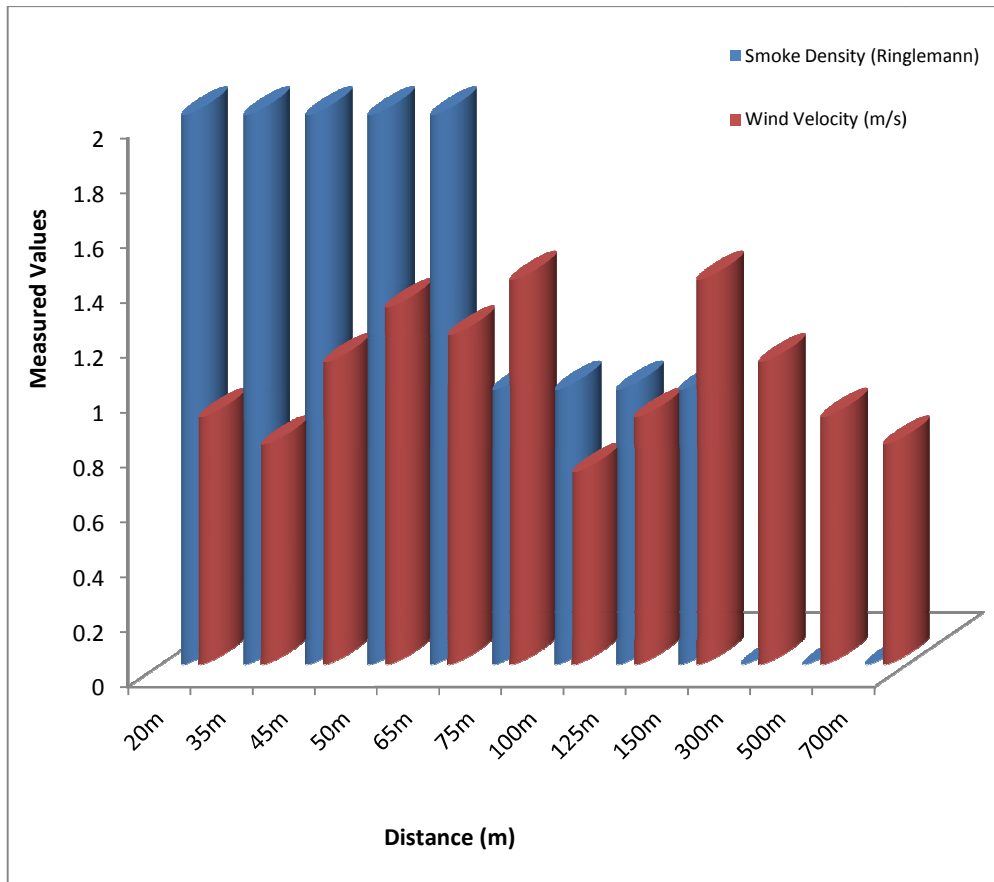


Fig. 6. Bar Chart plot of measured Smoke density and Wind Velocity at varying distance

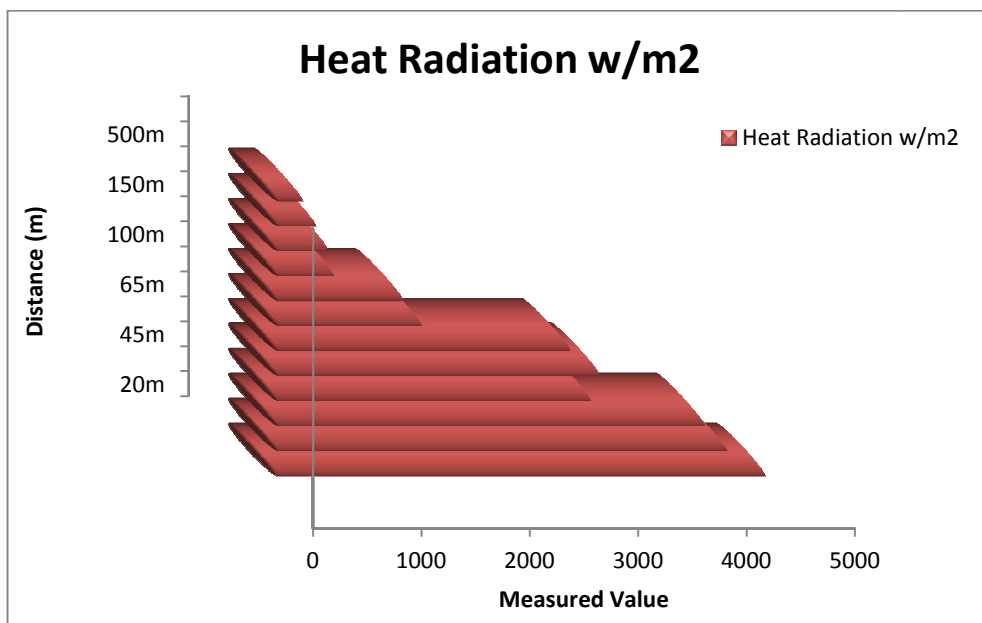


Fig. 7. Plot of measured Heat Radiation at varying distance

4. CONCLUSION

It is safe to conclude that gas flaring not only produces excessive heat which alters the temperature of the environment, but also causes gaseous pollutants to be present in the environment which may have adverse effects on the inhabitants and thus on the socio-economic activities of Ebocha community. At measured distances of 20m, 35m, 50m and 75m from the flare point, CO values of $18.80\mu\text{g}/\text{m}^3$, $19.08\mu\text{g}/\text{m}^3$, $10.47\mu\text{g}/\text{m}^3$ and $11.40\mu\text{g}/\text{m}^3$ respectively were measured, which exceeded the DPR recommended standard of $10\mu\text{g}/\text{m}^3$. Air pollutants measure has shown that there was a massive decrease in pollution as the distance from flare point increases. This further showed that environs close to flare sites at Ebocha community are more likely to suffer harm as compared to communities far off. Hence, there is need for adequate maintenance of flare machinery and proper replacement of old equipment to curtail the effect of flared gases and meteorological factors within host communities. Results from this study also showed that the temperature of the environment returns to normal at about 450m away from the flare stack. Therefore, we recommend that urban and regional planning agencies should implement policies ensuring that residential buildings are located at minimum distances of 700-1000m off gas flaring points.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. The World Bank. Little Green Data Book 2015. Available: <https://openknowledge.worldbank.org/bitstream/handle/10986/22025/9781464805608.pdf>
2. Fagbeja MA, Hill J, Chatterton T, Longhurst J, Akinyede J. Residential-Source Emission Inventory for the Niger Delta—A Methodological Approach. *J. Sustain. Dev.* 2013;6:98–120. [CrossRef]
3. Adoki, A. Air Quality Survey of some locations in the Niger Delta Area. *J. Appl. Sci. Environ. Manag.* 2012;16:125–134.
4. Uyigüe E, Agho M. Coping with Climate Change and Environmental Degradation in the Niger Delta of Southern Nigeria. Community Research and Development, Centre Benin City. Available: http://priceofoil.org/content/uploads/2007/06/07.06.11%20-%20Climate_Niger_Delta.pdf (accessed on 26 August 2017).
5. World Health Organization (WHO). WHO Releases Country Estimates on Air Pollution Exposure and Health Impact. Available: <http://www.who.int/mediacentre/news/releases/2016/air-pollution-estimates/en/> (accessed on 23 July 2017).
6. Godson REEA, Sridhar MKC. Industrial Emissions and Health Hazards among Selected Factory Workers at Eleme, Nigeria. *Int. J. Environ. Health Res.* 2009;9:43–51.
7. Ubong IU, Ubong UU, Ubong UE, Ukonta R, Ishmael D. Distribution of Particulate Matter in Cawthorne Channels Air Basin in Nigeria. *Environ. Pollut.* 2015;4:19–26. [CrossRef]
8. NASRDA, Nigeriasat-1: A Solution to Sustainable National Development Challenges, NASRDA NEWS, 2005;1(3).
9. Abdulkareem, A. S., Odigure J. O. and Abenege, S. "Predictive Model for Pollutant Dispersion from Gas Flaring: A Case Study of Oil Producing Area of Nigeria," *Energy Sources*, 2009;Part A;31(12):1004-1015. DOI:10.1080/15567030801909318.
10. Aghalino, SO. "Gas Flaring, Environmental Pollution and Abatement Measures in Nigeria, 1969-2001," *Journal of Sustainable Development in Africa.* 2009;;11(4):219-238.
11. Nwachukwu AN, Chukwuocha EO, Igbudu OA Survey on the Effects of Air Pollution on Diseases of the People of Rivers State, Nigeria. *Afr. J. Environ. Sci. Technol.* 2012;6:371–379. [CrossRef]
12. World Health Organization (WHO). Air Pollution. (accessed on 26 July 2017).

- Available:<http://www.who.int/ceh/risks/cehair/en/>
(assessed on 1 August 2017).
13. World Health Organization (WHO). Air Pollution Levels Rising in Many of the World's Poorest Cities. Available:<http://www.who.int/mediacentre/news/releases/2016/air-pollution-rising/en/>
(accessed on 23 July 2017).
 14. Rim-Rukeh, A. An Assessment of Indoor Air Quality in Selected Households in Squatter Settlements Warri, Nigeria. *Adv. Life Sci.* 2015;5:1–11. [CrossRef]
 15. United Nations Environment Program (UNEP). Environmental Assessment of Ogoni land. Available:http://postconflict.unep.ch/publications/OEA/UNEP_OEA.pdf
(accessed on 29 October 2017).
 16. Weli EV. Atmospheric Concentration of Particulate Pollutants and its Implications for Respiratory Health Hazard Management in Port Harcourt Metropolis, Nigeria. *Civ. Environ. Res.* 2014;9:11–17.
 17. Nigeria Population. World Population Review; 2017. Available:<http://worldpopulationreview.com/countries/nigeria-population/>
(accessed on 2 July 2017).
 18. Nkwocha EE, Egejuru RO. Effects of Industrial Air Pollution on the Respiratory Health of Children. *Int. J. Environ. Sci. Technol.* 2008;5:509–516. [CrossRef]
 19. Onwuchekwa CA, Asekomeh EG. Geriatric Admissions in a Developing Country: Experience from a Tertiary Centre in Nigeria. *Ethn. Dis.* 2009;19:359–362. [PubMed]

© 2021 Ehumadu et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
<http://www.sdiarticle4.com/review-history/69064>