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Spatial Assessment of Health Outcomes and Complications of Gas Flared Pollutants on Residents within Operational Radius of Agbada II Flow Station, Port Harcourt, Rivers State

Imiete Godspower; Dappa Ibiewotogha Daddy; Kpang MeeluBari Barinua Tsaro

1. Department of Environmental Management, Faculty of Environmental Sciences, Rivers State University, Nkpolu-Oroworukwo, Port Harcourt, Nigeria
2. Department of Geography and Environmental Management, Faculty of Social Sciences, University of Port Harcourt, Port Harcourt, Nigeria

*Correspondence: Kpang MeeluBari Barinua Tsaro

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Abstract

Gas flaring do not only contribute to contamination and deterioration of the air quality of surrounding areas but also has adverse environmental and public health implications. The main focus of this study was to unravel the health outcomes and complications prevalent among residents around Agbada II flow station in Rivers State. The experimental research design was adopted while the data for this study were sourced from both primary and secondary sources. The primary data included air quality parameters recorded at various sampled locations while the secondary data included different health challenges obtained from the archive of the health centre within the flaring sites in the study area. The statistical tool employed to analyze the data were Pearson Product Moment Correlation and Analysis of Variance (ANOVA). The relationship between O_3, NO_2, SO_2, VOC and $PM_{2.5}$, CH_4, H_2S and the health challenges in the area showed positive correlation at $P<0.05$. On the other hand, ANOVA revealed that the spatial variation in health challenges within the flared pollutants area was equally significant at $P<0.05$ (CD-. F=10.40109, sig = 0.00, Cancer F=12.30989, sig = 0.00; ND- F=13.32089, sig = 0.00; GD-F=12.30989, sig = 0.00; KD- F=9.21989, sig = 0.00; LD- F=5.32989, sig = 0.00; SD-F=8.81089, sig = 0.00; A- F=9.41989, sig = 0.00; B- F=14.10089, sig = 0.00 and COPD-F=32.21979, sig = 0.00). Arising from the foregoing, reduction in the quantity of gas flared at source, diversion of ecological fund into massive investment in functional, accessible and affordable healthcare infrastructure, stringent enforcement of zero tolerance for defaulting companies on the regulations and laws on flaring of gases, enactment of laws prohibiting construction of housing facilities in proximity to gas flaring sites were recommended for urgent takeoff.

Keywords: Complications, Assessment, Radius, Spatial, Enactment.

Introduction

Gas flaring, the disposal of gas through stacks in an open-air flame, is a common feature in the processing of crude oil, especially in oil-rich regions of the world. It is mainly used to dispose of associated gases with crude oil to make it more economically useful; and this has been regular practice within the Nigerian oil and gas industry for decades. According to Dung, Bombom & Agusomu (2008), composition of gas flared pollutants consists of methane and other gaseous components which vary with the individual production gas plants. Gas flared pollutants can be roughly described as 90% methane, with 1.5 – 2.0% carbon dioxide, 3.9 – 5.3% ethane, 1.2 – 3.4% propane, 1.4 – 2.4% heavier hydrocarbons and trace amount of sulphur (Brown, Kuechler, Verberckmoes, Puttemans, & Silverberg, 2010). Gas pollutants emitted in the presence of atmospheric compounds such as oxygen (O_2) and water (H_2O), NOx (NO + NO_2) reacts to form nitrate ion (NO_3^-) and SO_2 reacts to form sulphate ion (SO_4^{2-}). Both NO_3^- (from NOx emissions) and SO_4^{2-} (from SO_2 emissions) contribute significantly to acid rain which leads to poor public health amongst others. The rates of emission of pollutants from gas flaring depend on a number of factors including, but not limited to, fuel composition and quantity, stack geometry, flame/ combustion characteristics, and prevailing meteorological conditions (Brown *et al*., 2010). In a related development, Ite & Ibok (2013) noted that global flaring and venting of petroleum associated gas is a significant source of greenhouse gas emissions and airborne contaminants that has proven difficult to mitigate over the years. In the petroleum industry, poor efficiency in the flare systems often result in incomplete combustion which produces a variety of volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs) and inorganic contaminants. Over the past fifty years, gas flaring and venting associated with petroleum exploration and production in the Nigeria's Niger Delta has continue to generate complex consequences in terms of energy, human health, natural environment, socio–economic environment and sustainable development. In some oil–producing host communities, most flaring and venting systems are located in close proximity to residential areas and/or farmlands; and the resultant emissions potentially contribute to global warming as well as some local and/or regional adverse environmental impacts.

Burning of natural gas associated with oil extraction takes place because of technical, regulatory, and/or economic constraints. This causes more than 350 million tons of CO_2 emissions every year, with serious harmful impacts from methane that has not been combusted and black carbon emissions (World Bank, 2018). The hydrocarbon compounds such as benzene, naphthalene, styrene, toluene, and xylene found in the flaring of associated gas affect health and safety of the local people in Nigeria. It is reported that breathing particulate matter which are linked to gas flaring result into aggravated asthma, increase in respiratory symptoms like coughing and difficult breathing, chronic bronchitis, decreased lung function, and premature death; and also health issues such as pneumonia and cases of leukaemia are linked to gas flaring. Thermal air pollution from gas plants also affects the microbial populations, which participate in organic matter decomposition and nitrogen formation process resulting in a decline in organic matter and total nitrogen, as well as microbial populations, humid (top soil) formation, nutrient availability and soil fertility. Therefore, air pollutants emanating from gas plants in adversely affect soil fertility and biogeochemical nutrient cycles and the negative effects of physic-chemical properties of the soil subsequently impact on food web and food chain due to modification of the microclimate and man's dependent on soil yield, biomass and biodiversity for socio-economic activities (Brown *et al*., 2010). According to Ajugwo (2013), the effects of air pollutants within the vicinity of gas plants on human health range from nausea and difficulty in breathing or skin irritation, to cancer, birth defects, serious developmental delays in children, and reduced activity of the immune system which leads to several diseases that are traceable to air pollution. Therefore, the threat to resident health in the vicinity of gas flared pollutants cannot be undermined. Arising from the foregoing, this study seeks to assess the health outcomes and complications associated with air pollutants among residents in the vicinity of flared pollutants in Rivers state.

Materials and Methods

Study Area

It lies between latitudes 4°55'50"N – 4°56'10"N and longitudes 7°0'50"E – 7°1'20"E. The study was carried out within the Agbada II flow station in Rivers State. The state has a population of 5,185,420 with a landmass of 10,378 km^2 and borders Imo and Abia States to the north, Akwa-Ibom State to the East and Bayelsa and Delta States to the West.

Sampling points

To ensure spatial coverage and avoid point specific measurement, 6 sampling points were selected, 200m, 400m, 600m, 800m, 1000m and 2000m and air quality parameters were measured during the climatological hours of 00:00hrs, 06:00hrs, 12:00hrs and 18:00hrs in alignment with Weli, Adegoke & Kpang (2016) as shown in Figure1below.

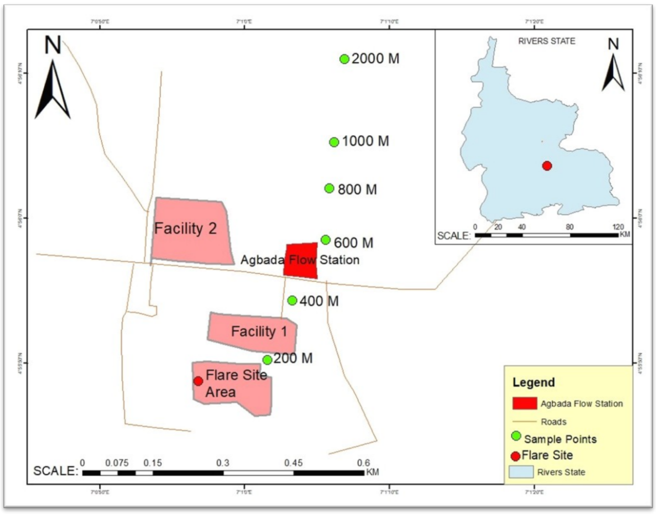

Figure 1: Sampling Points around Study area

Determination of Air Quality

The multi gas detector was used in collecting the concentrations of the pollutants and the parameters measured include CO, O_3, NO_2, SO_2, $PM_{2.}$, CH_4, VOC and H_2S.

Determination of Health outcomes Associated with Flared Pollutants in the Area

The health outcomes and complications associated with flared pollutants in the area was obtained from the archive of government health facility within the area and the complications recorded include Chronic Obstructive Pulmonary Disease (COPD), Bronchitis, Asthma, Skin Diseases, Liver Disease, Kidney Disease, Gastrointestinal Disorders, Neurological Disorders, Cancer and Cardiovascular Disease.

Data Analysis

The Pearson Product Moment Correlation statistic was employed to test the relationship between the concentration of flared pollutants and health challenges encountered by residents in the study area whereas Analysis of Variance (ANOVA) was employed to analyze the variation in the concentration of pollutants across the location under investigation. The mathematical expressions of the Pearson equations are shown below:

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

- r = Pearson Coefficient
- n= number of the pairs of the stock
- $\sum xy$ = sum of products of the paired stocks
- $\sum x$ = sum of the x scores
- $\sum y$= sum of the y scores
- $\sum x^2$ = sum of the squared x scores
- $\sum y^2$ = sum of the squared y scores

The mathematical formula for ANOVA is given by the formula below (Akuezuilo & Agu, 2002):

$$TSS = \sum x^2 - \frac{(\sum x)^2}{N}$$

$$BSS = \frac{(\sum x_1)^2}{n_1} + \frac{(\sum x_2)^2}{n_2} + \frac{(\sum x_3)^2}{n_3} + \frac{(\sum x_4)^2}{n_4} - \frac{(\sum x)^2}{N}$$

WSS = TSS – BSS

Where:

- TSS = Total Sum of Squares
- BSS = Between Sample Sum of Squares
- WSS = Within Sample Sum of Squares
- n_1 … n_3 = Number of Samples means being compared
- N = Total items of all groups

Table 1: Pollutant Concentrations at different times of the day in the area

Time of day	CO (PPM)	NO_2 (PPM)	O_3 (PPM)	SO_2 (PPM)	$PM_{2.5}$ (µg/m³)	CH_4 (PPM)	VOC (PPM)	H_2S (PPM)
Morning	205.17	199.63	172.73	0.10	107.18	156.13	18.67	3.63
Afternoon	274.43	228.50	185.83	0.40	131.68	168.77	21.70	5.01
Evening	253.50	196.40	163.70	0.10	106.00	170.66	20.24	4.40

The data presented in Table 1 show the concentration of atmospheric pollutant at different time of the day from gas flaring station in Rivers state. The Table shows that there is variation in the volume of pollutants in the morning, afternoon and evening. The volume of carbon monoxide in the morning is 205.17ppm, afternoon 274.43ppm and evening is 253.50ppm. It is evident that there is a significant increase in the volume of carbon monoxide in the afternoon which can be adduced to the influence of weather characteristics. The concentration of Ozone in the morning is 172.73ppm, afternoon is 185.83ppm and evening is 163.70ppm and from the Table other pollutants assumes the same pattern except methane that show higher concentration in the evening, with only slight variation between the morning, afternoon and evening concentration.

Table 2: Health challenges associated with flared pollutants in the area

	Health challenges									
	Health challenges									
Distance	CD	C	ND	GD	KD	LD	SD	A	B	COPD
200	95	51	5	433	16	5	92	19	3	12
400	54	29	4	257	9	3	63	16	1	4
600	32	20	2	137	6	1	48	11	0	3
800	26	15	1	111	3	1	26	5	1	2
1000	17	8	0	41	1	0	15	2	1	1
2000	10	0	0	23	1	1	10	1	0	1
Total	234	123	12	1002	36	11	254	54	6	23

NB: CD-Cardiovascular Diseases, C-Cancer, ND-Neurological Disorders, GD-Gastrointestinal Disorders, KD-Kidney Diseases, LD-Liver Diseases, SD-Skin Diseases, A-Asthma, B-Bronchitis and COPD-Chronic Obstructive Pulmonary Disease

The data presented in Table 2 show the susceptibility of residents to different ailments induced by gas flaring activities in the area and it is explicit as shown in the Table that the number of victims exposed to different kinds of ailments associated with flared pollutants reduces as the distance from the flaring sites increases. It is evident that 95 persons at 200m circumference are affected by cardiovascular diseases, 54 persons at 400m, 32 persons at 600m, 26 persons at 800m, 17 person at 1000m and 10persons at 2000m. The total number of persons affected by cardiovascular diseases show high occurrence and severity of the disease. The number of people exposed to bronchitis in the place is few, but the area within 200m recorded 3 persons, while the area from 1000m to 2000m did not record any person exposed to bronchitis within the circumference of the gas flaring point. The occurrence and exposure to Gastrointestinal Disorders in the area is alarming given that a total number of 1002 persons were found to be victims of the said disease. The number of people reportedly affected by Gastrointestinal Disorders reads as follows: 200m is 433 persons, 257 persons at 400m, 137 persons at 600m, 111 persons at 800m, 41 persons at 1000m and 23 persons at 2000m. The difference between exposure at point 200m and 2000m is substantial and show the level of vulnerability to the disease. This pattern is also replicated for the exposure to kidney diseases where 16 persons living close to the flare points are affected, while only one person is affected in residencies around 2000m in the place.

Table 3: ANOVA summary of the spatial variation in health challenges within the gas flared site

Health Challenges	Mean values (Distance)						F-values	Sig
	200(m)	400(m)	600(m)	800(m)	1000(m)	2000(m)		
CD	95.1230	54.1110	32.1110	26.1110	17.1121	10.1121	10.40109	*0.00
C	51.1110	29.1110	20.1110	15.1110	8.1121	0.1121	12.30989	*0.00
ND	5.1210	4.1110	2.1110	1.1110	0.1121	0.1121	8.30999	*0.00
GD	433.1320	257.1110	137.1110	111.1110	41.1121	23.1121	13.32089	*0.00
KD	16.0101	9.0101	6.0130	3.0130	1.1121	1.1121	9.21989	*0.00
LD	5.0101	3.0101	1.0130	1.0130	0.1121	1.1121	5.32989	*0.00
SD	92.0101	63.0101	48.0101	26.0101	15.0101	10.0130	8.81089	*0.00
A	19.0100	16.0101	11.0101	5.0101	2.0101	1.0130	9.41989	*0.00
B	3.0101	1.0101	0.0101	1.0101	1.0101	0.0130	14.10089	*0.00
COPD	12.0101	4.0101	3.1121	2.1121	1.1121	1.1121	32.21979	*0.00

NB: CD-Cardiovascular Diseases, C-Cancer, ND-Neurological Disorders, GD-Gastrointestinal Disorders, KD-Kidney Diseases, LD-Liver Diseases, SD-Skin Diseases, A-Asthma, B-Bronchitis and COPD-Chronic Obstructive Pulmonary Disease

The result presented in Table 3 show the outcome of analysis of variance on the health challenges experienced at different intervals from the gas flaring site in Rivers state. ANOVA show that the mean difference for Cardiovascular Diseases at different intervals from the gas flaring site in Rivers state is significant at the $P<0.05$ level. $F=10.40109$, sig = 0.00. Since the significant value is 0.00 which is below 0.05

(p value), it indicates that there is a statistically significant difference in the spatial variation in the exposure and occurrence of cardiovascular diseases across the different interval from the gas flaring sites in Rivers state. The case of cancer F=12.30989, sig = 0.00, Neurological Disorders F=13.32089, sig = 0.00, Gastrointestinal Disorders F=12.30989, sig = 0.00, Kidney Diseases F=9.21989, sig = 0.00, Liver Diseases F=5.32989, sig = 0.00, Skin Diseases F=8.81089, sig = 0.00, Asthma F=9.41989, sig = 0.00, Bronchitis F=14.10089, sig = 0.00, and Chronic Obstructive Pulmonary Disease F=32.21979, sig = 0.00.

Table 4: The relationship between pollutants concentration and health challenges among residents in the area

Health issues	CO (PPM)	NO_2 (PPM)	O_3 (PPM)	SO_2 (PPM)	$PM_{2.5}$ (µg/m^3)	CH_4 (PPM)	VOC (PPM)	H_2S (PPM)
CD	*0.44	*0.22	*0.33	*0.26	*0.41	*0.44	*0.42	*0.65
C	*0.62	*0.31	*0.34	0.19	*0.52	*0.50	*0.67	*0.45
ND	*0.28	*0.46	*0.42	*0.36	*0.33	*0.42	*0.61	*0.72
GD	*0.47	*0.31	*0.32	*0.34	*0.47	*0.31	*0.34	*0.52
KD	*0.31	*0.48	*0.66	*0.47	*0.36	*0.47	*0.52	*0.66
LD	*0.38	*0.61	*0.39	*0.69	*0.41	*0.28	*0.46	*0.48
SD	*0.51	*0.22	*0.21	*0.71	*0.39	*0.26	*0.72	*0.66
A	*0.49	*0.40	*0.35	*0.37	*0.53	*0.45	*0.35	*0.64
B	*0.29	*0.25	*0.76	*0.23	*0.42	*0.36	*0.46	*0.49
COPD	*0.33	*0.21	*0.47	*0.41	*0.63	*0.57	*0.78	*0.42

NB: CD-Cardiovascular Diseases, C-Cancer, ND-Neurological Disorders, GD-Gastrointestinal Disorders, KD-Kidney Diseases, LD-Liver Diseases, SD-Skin Diseases, A-Asthma, B-Bronchitis and COPD -Chronic Obstructive Pulmonary Disease. ***significant at $p<0.05$, n=30**

The data presented in Table 4 show the relationship between the concentration of pollutants and health challenges in Rivers state. The intention of the hypothesis is to find out the extent to which the occurrences of different ailments are induced by the volume of pollutants from gas flaring sites in the Rivers State. The relationship between carbon monoxide and cardiovascular diseases show positive correlation of 0.44, Cancer 0.62, Neurological Disorders 0.28, Gastrointestinal Disorders 0.47, Kidney Diseases 0.31, Liver Diseases 0.38, Skin Diseases 0.51, Asthma 0.49, Bronchitis 0.29 and COPD-Chronic Obstructive Pulmonary Disease. 0.33 is significant at $p<0.05$. Evidently, all the concentration of carbon monoxide show positive relationship with the prevalence of all the reported diseases, in the study area. The relationship between O_3, NO_2, SO_2, VOC and $PM_{2.5,}$ $CH_{4,}$ H_2S and the reported health challenges also showed positive correlation.

Discussion of Result

The pollutants around gas flared stations at different times of the day in the study area

This study found that there is a significant variation in the concentration of pollutants around gas flaring communities in the morning, afternoon and evening. The data collected and analyzed show that the concentration of Carbon monoxide, Ozone, Sulphur oxide, Nitrogen oxide, $PM_{2.5}$, and Hydrogen sulphide is higher in the afternoon hours and lower in the morning and in the evening hours. However, the concentrations of pollutant at all time of the day show severe consequences for the environment with attendant public health effects. Previous studies have adduced the variation of air pollutants at different time of the day to the influences of meteorological parameters such as temperature and relative humidity (Odjugo, 2008). Although, flaring of gases in the area continues sequel to the processing of crude oil, this study reported disparity in air quality at different time of the day. Obi et al. (2021) contend that levels of air pollution from different sources reduce in the morning because of lower temperature, and the air temperature is cooler, denser with oxygen. They also argue that people feel less discomfort in the morning around gas flaring communities than in the evening. Other reports have added that the reduced industrial activities in the night also manifest in cleaner air in communities close to the source of the pollution, but this theory on lower level of temperature as a result of reduced industrial activities does not fully agree with the pattern of gas flaring that is nonstop. The outcome of this study on the variation in air quality in different hours of the day is consistent with Nwachukwu, et al. (2022) in the quality of air in gas flaring locations in Rivers State during the rainy and the wet seasons. They measured ambient air quality in the morning, afternoon and evening in each of the four stations investigated for three months. They reported six potential air pollutants in the study area such as suspended particles such as particulate matter ($PM_{2.5}$, PM10) Carbon (II) Oxide (CO), Nitrogen (iv) Oxide (NO_2), Sulphur (IV) oxide (SO_2), methane (CH_4), volatile organic compound (VOC) with reference to meteorological parameters like relative humidity, ambient temperature, and wind speed and direction. The results of the study showed that the mean concentration of the air pollutants in the dry season and rainy season exceeded the limits of the World Health Organization (WHO). The study concluded that air quality in Aluu is polluted with various pollutants particularly during the dry season.

The spatial variation in pollutant concentration and prevalent health challenges among residents in the study area

The result of the study is consistent with findings of previous studies on the effects of gas flaring on the health of residents around gas flaring communities in Rivers State. The result clearly show that residents living at different intervals from the gas flaring locations are at great risk to a variety of health challenges such as cardiovascular diseases, Cancer, Neurological Disorders, Gastrointestinal Disorders, Kidney Diseases, Liver Diseases, Skin Diseases, Asthma, Bronchitis, and Chronic Obstructive Pulmonary Disease. Notwithstanding, it is conspicuous from the study that the number of residents affected by the varying diseases reduced substantially with increasing distance from the gas flare point. The study also found that the concentrations of air pollutant vary across the vicinity of the flare site, and the amount of pollutant released into the environment possesses the character to compromise public health. However, the residents that live farther from the gas flaring point are less vulnerable given that some of the ailments investigated are not severe across distance farther from the flare location. Among residents at 2000m away from the gas flaring point, there was no record of any case of bronchitis, Neurological Disorders, cancer and Chronic Obstructive Pulmonary Disease. The findings of this study are also in agreement with Obi (2021a) when he reported the prevalence of protracted ailments in communities close to the gas flaring points in the Niger Delta region. Obi (2021) relied on the perception of the people and thematic analysis to evaluate the experiences of the residents' in oil communities within the circumference of gas flaring sites. He reported that the residents are aware of their vulnerability to health challenges as a result of the decades of nonstop flaring of gases in the region, but while some of the people have migrated to safer communities, others that are attached to ancestral communities and without the income to start a new life in other communities have remained stuck in the toxic environment. Obi et al (2021) recognized carcinogens such as benzopyrene, benzene, carbon disulphide (CS_2), carbonyl sulphide (COs) and toluene; metals such as mercury, arsenic and chromium; sour gas with H_2S and SO_2; nitrogen oxides (NOx); carbon dioxide (CO_2) and methane (CH_4) which contributed to the GHGs.14 associated gases flared into the atmosphere contained GHGs as well as other poisonous substances such as dioxins, benzene, toluene, nitrogen and SO_2. The implications of these high concentration on public health is dire, and with economic consequences. *Bakpo & Solomon (2018) reported* asthma, acute leukemia and a variety of other blood disorders, immune dysfunction, respiratory illness, spontaneous abortion, reproductive disorders, endocrine dysfunction, skin disorder, heat irritation, sunstroke, heat exhaustion, autoimmune rheumatic diseases, thyroid cancers, reduced life expectancy and deformities in children in communities exposed to gas flaring sites.

The relationship between pollutants concentration and health challenges among residents in the area

All the pollutants showed correlation with the ailments under investigated, but the strength of the correlation varied. The reports in the nexus between air quality and public health of residents is consistent with the reports of Kokate et al. (2022) that air pollution is a major public health threat in developed and developing countries, they reported that increasing trend of resource extraction, processing and industrialization manifest in proportional emission of pollutants into the atmosphere. The close proximity of vulnerable communities to source pollution such as gas flaring do not only destroy the natural environment that provides a support system for the rural economies, the health of the people is also greatly compromised. Absence of efficient healthcare services at the primary, secondary and tertiary level has exacerbated the health challenges in the vulnerable communities. Many gas flaring station in the Nigeria Delta such as the ones in Rivers state are in the rural communities where primary healthcare facilities are lacking, and the people do not have the finance to seek medical services to protracted ailments induced by the prolonged flaring of gases, many of them are left to fate. This is also manifested in slow pace of economic activities given the nexus between sound public health and economic viability in communities. The outcome of this study is consistent with Alimi & Gibson (2022) that hold that exposure to $PM_{2.5}$ could induce chronic and adverse respiratory problems for communities. Also, Alimi & Gibson (2022) assert that the exposure to $PM_{2.5}$ that is above the limit of the WHO can cause diseases to the cardiovascular and respiratory system, and this could provoke stroke, lung cancer and chronic obstructive pulmonary disease (COPD). Alimi & Gibson (2022) reported that prenatal exposure to high level of air pollutants could cause behavioral and psychological problems, and hyperactivity disorder, anxiety and depression. Obi, Bwititi, & Ezekiel (2021) contend that the health of residents close to the gas flaring locations in the Niger Delta region is severely compromised. According to the authors, the wasteful incineration of gases has caused negative impacts on the flora, fauna and human health and livelihood in the region. Reports of the World Bank group indicate that gas flaring in Nigeria contributed more greenhouse gases (GHGs) such as carbon dioxide, methane, nitrous oxide, chlorofluorocarbons to the atmosphere than the combined contribution of gas flaring on GHGs in the Sub-Saharan African countries (Obi et al, 2021). A similar study by Ndinwa et al. (2020) investigated the health impacts of gas flaring activities in kwale communities. The study revealed that the residents are aware of the environmental consequences of prolonged gas flaring in their communities. Overwhelming 68% of the residents agreed that gas flaring activities induces different sicknesses among resident as they complained of excessive heat radiation and very high temperature.

Conclusion and Recommendations

Gas flaring is associated with crude oil processing and production and characterized with the release of gases, particulates, noise and heat, which do not only leads to substantial contamination and deterioration of the air quality, water and land and the flora inhabiting these natural systems but also have dire consequences on both the humans and the environment. This study revealed that there is significant variation in the concentration of pollutants from the gas flaring location at different intervals of 200m, 400m, 600m, 800m, 1000m and 2000m. It is also evident from the study that concentration of pollutants such as carbon monoxide, ozone, sulphur oxide, nitrogen oxide, $PM_{2.5}$, and hydrogen sulphide is higher than the air quality guidelines of the World health Organization. Although, correlation between the concentration of air pollutants and different health challenges showed disparity, a positive correlation between the prevalence of health challenges and the deterioration of air quality in the area was noted. The study show that more persons are affected and experiencing severe health challenges such as bronchitis, Neurological Disorders, cancer and Chronic Obstructive Pulmonary Disease in the residencies close to the flare points while less cases are reported in the interval of 2000m indicating that the vulnerability of residents to different health challenges vary with increase in distance from the flare sites. Consequent upon the findings of this study, the following recommendations were made:

- reducing the quantity of gas flared at source so as to mitigate the risks associated with gas flaring on air quality in the study area.
- Ecological funds allocated to the state should be invested in functional, accessible and affordable healthcare infrastructure at different levels with special department for residents that are exposed to varying degree of ailments induced by gas flaring activities.
- workable plans and implementable programmes and policies to achieve the federal government declaration to stop flaring of gases by the year 2030 and to achieve a milestone in the reduction of gas flaring activities by 2025 activated.
- Stringent enforcement of zero tolerance for defaulting companies on the regulations and laws on flaring of gases and proximate distance from residential communities by government is crucial.
- Legislation prohibiting the construction of housing facilities within the circumference of gas flaring sites/relocation of residents and communities within the vicinity of flaring sites should be enacted.
- Farming activities and other economic activities close to gas flaring points, and the drying of grains by residents within the vicinity of the gas flaring points as reported in the literature should be outlawed and strictly prohibited.

- Sensitization of residents on the health implications of gas flaring by NGO's, government agencies and the IOC's is worthwhile.

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