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Comparative Assessment of Health Challenges Prevalent Among Residents Around Gas Flaring Sites in Rivers and Bayelsa States

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Keywords

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Abstract

Purpose: *Gas flaring is a common practice in oil-producing developing countries like Nigeria basically because weak regulations and poor environmental monitoring pave way for that to happen. This economically wasteful and damaging process comes with huge health consequences on residents living close to the gas flare. This study attempted a comparative assessment of health challenges among residents in the vicinity of gas flared areas in Rivers and Bayelsa States. Both primary and secondary data were used for the study whereas the primary data included air quality parameters recorded at various sampled locations. On the other hand, the health challenges were assessed from the archives of the government health centers in the areas. Data analysis was done using Pearson Product Moment Correlation statistic (PPMC) and Analysis of Variance (ANOVA). The result shows that there is a significant reduction in the volume of pollutants with respect to distance from the flare sites at P<0.05. ANOVA showed that the mean difference for gases between the two sampled states was significant at the P<0.05 level. The PPMC showed that there was a significant correlation between atmospheric pollutant and human health challenges in the area at p<0.05 while the relationship between* 0_3, NO_2, SO_2, *VOC and* $PM_{2.5}$ *and the reported health challenges also showed positive correlation. . The study recommended reduction in the quantity of gas flared at source; enactment of laws prohibiting residential/farming activities close to the flaring sites; insistence on environmentally friendly technologies in operations of oil companies and zero tolerance for defaulting companies on regulations and laws on flaring of gases; synergy between government and NGO's to provide health education and sensitization of residents on impact of gas flaring among other recommendations.*

Introduction

Gas flaring is an integral part of crude oil production and processing resulting in substantial contamination and deterioration of the air quality, water and land and the flora inhabiting these biomes [1]. The World health report indicated that globally, 23 percent of death occurrences and 26 percent of children deaths ranging up to 4 million children under five every year are due to air pollutants from oil and gas industry [2,3]. Also, 85 out of 102 categories of diseases and injuries are influenced by environmental factors [4]. According to the World Health Organization (WHO), the interactions between humans and the environment affect the air quality, health disparities and a healthy life span. Avoidance of poor air quality can prevent about 13 million deaths yearly and avoid 13%–37% of the world's health risk disease burden, such as 41% of deaths from lower respiratory infections [5]. Thus, sound environmental air quality involves preventing or controlling pollutants from gas plants interactions between the environment and humans. According to Dung, Bombom & Agusomu [6], 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 [7]. From the perspective of health challenges among residents in the vicinity of gas flared pollutants, Emovon, Kareem, & Adeyeri [8] attributed their risk to premature death, respiratory disorders such as asthma, cancer, hypertension, birth defects, diabetes, cardiovascular (CVD) and kidney disease amongst others. Around 2 million people living within 4 kilometres of flare sites across are exposed to the black fumes and toxins emission. It is reported that over 67 per cent of the residents within gas plant locations frequently report respiratory problems, skin rashes, eye irritations, irritation of the nose, throat; coughing; shortness of breath;

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dizziness and weakness. Gas flared pollutants can predispose the body to specific organ dysfunctions, particularly in those with compromised immune systems [6]; also, air pollution can enter our bloodstream and contribute to lung diseases leading to hospitalizations, cancer, or even premature death. More importantly, Dung et al. [6] opined that effects of gas flared pollutants on health of residents within gas plant radius are very alarming in Rivers and Bayelsa state. It is against this backdrop that this study seeks to undertake a comparative assessment of health challenges prevalent among residents in the vicinity of flaring sites in Rivers and Bayelsa States.

Materials and Methods

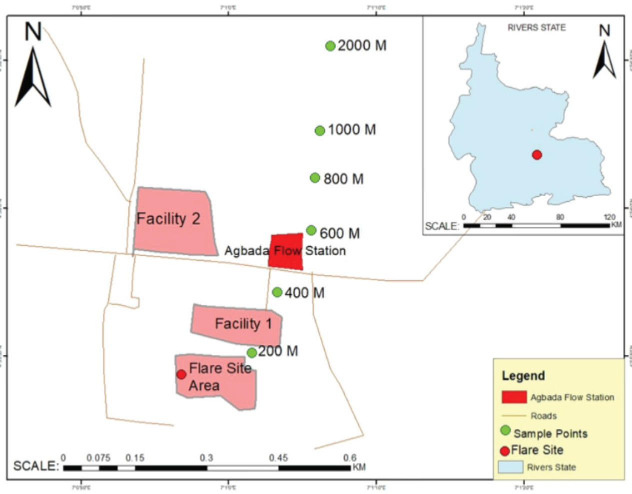

Figure 1A: *Sampling Points around Study area in Rivers State*

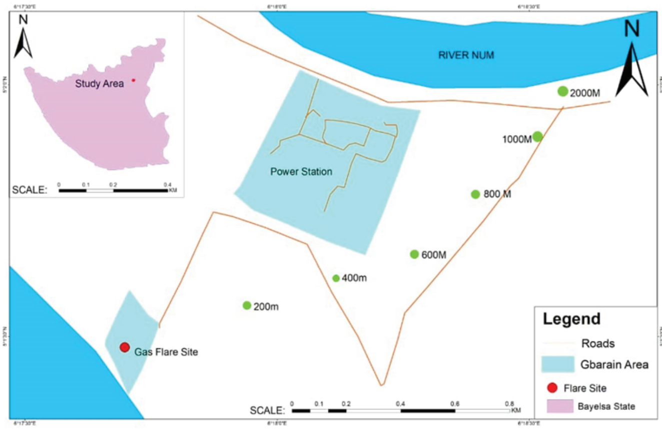

Figure 1B: Sampling Points around Study area in Bayelsa State

The study was carried out in Rivers and Bayelsa States, Niger Delta region with particular focus on Agbada II flow station (Rivers) and Gbarain gas power plant (Bayelsa). Rivers State has a population of 5,185,420 with a landmass of 10,378 km^2 while Bayelsa State has a population of 1, 703, 358 with a landmass of 11,007 km^2 (NPC, 2006). Rivers State boarders Imo and Abia State to the north, Akwa-Ibom State to the East and Bayelsa and Delta States to the West whereas Bayelsa State shares boundary with Rivers State to the East and Delta State to the West, with the waters of the Atlantic Ocean dominating its southern boarders. Rivers and Bayelsa states in the Niger Delta falls within the tropical rainforest climate or the equatorial monsoon, designated by the Koppen climate classification as "Af" which is influenced by the monsoon running from the South Atlantic Ocean, (maritime tropical) air mass, a warm moist sea to land seasonal wind. It also has warm and high humidity characteristics which gives it a strong propensity to rise and produce abundant rainfall as an evidence of the condensation of water vapour in the swiftly rising air [9]. The data used in this study were sourced from both primary and secondary sources. 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 [10] as indicated in Figure 1 and 2. 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. The gases were measured in parts per million (ppm) while SPM were measured directly in microgram per cubic meters (ug/m^3).

On the other hand, the health outcomes and complications associated with flared pollutants in the area was obtained from the archives of government health facilities within the areas and the complications recorded include chronic obstructive pulmonary disease (COPD), bronchitis, asthma, skin diseases, liver disease, kidney disease, gastrointestinal disorders, neurological disorders, cancer and CVD.

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:

$$r = \frac{n\left(\sum xy\right) - \left(\sum x\right)\left(\sum y\right)}{\sqrt{\left[n\sum x^2 - \left(\sum x\right)^2\right]\left[n\sum y^2 - \left(\sum y\right)^2\right]}} \qquad (1)$$

Where,

- 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 [11]:

$$TES = \sum x^2 - \frac{\left(\sum x\right)^2}{N} \qquad (2)$$

$$ESS = \frac{\left(\sum x_1\right)^2}{n_1} + \frac{\left(\sum x_2\right)^2}{n_2} + \frac{\left(\sum x_3\right)^2}{n_3} + \frac{\left(\sum x_4\right)^2}{n_4} - \frac{\left(\sum x\right)^2}{N} \qquad (3)$$

WSS = TSS – BSS (4)

Where:

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

Table 1. *Pollutant volumes at different times of the day in Rivers and Bayelsa States*

Location	Time of day	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)
Rivers	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
Bayelsa	Morning	205.17	196.13	177.73	0.10	99.18	161.13	20.67	3.63
	Afternoon	266.13	219.70	189.53	0.10	114.38	176.47	21.90	4.41
	Evening	251.50	194.90	168.70	0.10	102.00	175.66	21.24	4.30

Data Presentation

The data presented in Table 1 show the concentration of atmospheric pollutant at different time of the day from gas flaring stations in Rivers and Bayelsa 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 case of ozone show that the volume in the morning is 172.73ppm, afternoon is 185.83ppm and evening is 163.70ppm which is also a replication of the pattern of concentration of other pollutants except methane that show higher concentration in the evening, with only slight variation between the morning, afternoon and evening concentration in the River State. The volume of $PM_{2.5}$ shows significant variation between the morning hours (99.19ppm), the afternoon hours (114.38) and evening hours (102.00ppm). Evidently, the volume of PM2.5 is higher in the afternoon that what is experienced in the morning and in the evening in Bayelsa state. The concentration of Sulphur oxide did not variation across different time of the day with 0.10ppm in the morning, afternoon and evening hours. There is a slight difference between the volume of hydrogen sulphide in the morning (3.63ppm) and in the afternoon (4.41ppm) and evening (4.31), but the volume of hydrogen sulphide in the afternoon is also higher that other time in the day. The case for nitrogen oxide also shows that the volume in the afternoon is higher with 196.33ppm in the morning, 219.70ppm in the afternoon and 194.90ppm in the evening. 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 analysis show that the amount 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 in different time of the day to the influences of meteorological parameters such as temperature and relative humidity [12]. While the flaring of gases in the two oil and gas producing states have remained constant for decades since the commercial exploitation and processing of crude oil, this study reported disparity in air quality at different time of the day. Obi et al. [13] 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. Perception studies in vulnerable communities carried in the Niger Delta region have reported that the rate of flaring gas does not reduce in the night, and the light is seen from different locations which are also very disturbing. Gobo, Richard & Ubong [14] added that relative humidity is also very critical in the differences seen in the quality of air in the morning, afternoon and evening hours, they argue that in many regions of the world, relative humidity tend to be higher in the morning due to cooler temperature and dew formation which can contribute to the feeling of cleaner air and lesser vulnerability in close communities. The natural process where plants releases oxygen through photosynthesis during the day and respire but consume oxygen while releasing carbon dioxide has been adduced to the variation in air quality in different hours. In the morning, plants begin photosynthesis again, contributing to a fresher atmosphere. The calmness of the wind in the morning reduces the volatility of atmospheric mixing which makes the air less polluted. When atmospheric mixing becomes more sporadic in the afternoon hours, and pollutants from different sources such as gas flaring, transportation, industrial activities and pollution from agriculture and construction are mixed, air pollution becomes more threatening and problematic. The outcome of this study is also consistent with Odu et al. [15] when they assert that flared gases trapped in the upper atmosphere may cause radiation to take place within the immediate environment of the flare site, thereby increasing the mean daily temperature beyond tolerance range. The outcome of this study on the variation in air quality in different hours of the day is consistent with Nwachukwu, et al. [16] in their report 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 WHO. The study concluded that air quality in Aluu is polluted with various pollutants particularly during the dry season.

***Table 2**. Spatial distribution of pollutants at various distances from the flared sites in Bayelsa and Rivers States*

Location	Distance	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)
Rivers	200	273.93	218.97	188.43	0.10	125.47	184.59	34.03	4.71
	400	259.60	213.63	181.77	0.10	120.17	175.25	25.33	4.51
	600	246.27	208.97	175.43	0.10	114.50	166.92	17.55	4.38
	800	235.60	205.63	170.77	0.10	110.50	160.25	14.91	4.25
	1000	228.60	202.30	166.10	0.10	109.67	154.59	13.72	3.81
	2000	221.60	198.97	161.43	0.10	108.83	148.92	15.07	3.81
Bayelsa	200	272.60	216.47	195.10	0.10	117.80	192.59	37.20	4.58
	400	258.27	211.13	188.43	0.10	112.50	183.25	28.50	4.38
	600	244.93	206.47	182.10	0.10	106.83	174.92	20.71	4.25
	800	234.27	203.13	177.43	0.10	102.83	168.25	18.07	4.11
	1000	227.27	199.80	172.77	0.10	102.00	162.59	16.89	3.68
	2000	220.27	196.47	168.10	0.10	101.17	156.92	18.23	3.68

The data presented in Table 2 show the variation in the volume of pollutant across different proximate intervals from gas flaring sites in Rivers and Bayelsa States. The data show that there is a significant reduction with distance from the flare sites. That is the volume of pollutant reduces as you move away from the bund wall of the flare sites. The case of carbon monoxide in Rivers state shows 273.93ppm at 200m, 259.60 at 400m, 246.27ppm at 600m, 235.60ppm at 800m, 228.60ppm at 1000 and 221.60ppm at 2000m. The margin between the volume of carbon monoxide at point 200m and point 2000m is 52.33ppm reduction in volume which is substantial. The case of Sulphur oxide showed uniform concentration across different intervals from the flare point with 0.10ppm in River state. But evidently, the table show that the concentrations of all the other pollutants (NO_2, O_3, $PM_{2.5}$, CH_4, VOC and H_2S) show gradual reduction in concentration as you move away from the flare point. The pattern of concentration in Rivers state is slightly different in Bayelsa state where the concentration of volatile organic compound show 37.20ppm at 200m, 28.50ppm at 400m, 20.71ppm at 600m, 18.07ppm at 800mm, a slight reduction to 16.89ppm at 1000m, and increase to 18.23ppm at 2000m. The result of this study is consistent with previous studies on the effects of gas flaring on the health of residents around gas flaring communities in Bayelsa and Rivers state. Communities in different intervals from the gas flaring locations show different number of residents that are affected by cardiovascular diseases, cancer, neurological disorders, gastrointestinal disorders, kidney diseases, liver diseases, skin diseases, asthma, bronchitis, and COPD. This study reported that the number of residents affected by the aforementioned diseases reduced substantially with increasing distance from the gas flare point. Outcome of student t-test show that there is no significant variation in the vulnerability of residents to diseases in Rivers and Bayelsa States. The study also found that the concentration of air pollutant did not vary between Rivers and Bayelsa States, and the amount of pollutant released into the environment in the two states 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 farther from the flare location. Residencies at 2000m away from the gas flaring point did not record any case of bronchitis, neurological disorders, cancer and COPD. This is also similar to the case in Bayelsa where no record of asthma, bronchitis and COPD was recorded in the communities at the interval of 2000m. Evidently, the concentration of pollutants from gas flared station in the two states show positive relationship with the prevalence of all the reported diseases. What is significantly different is the level of vulnerability across different residencies from the gas flare point in each state. The findings of this study are also in agreement with Obi [13] when they reported the prevalence of protracted ailments in communities close to the gas flaring points in the Niger Delta region. Obi [13] relied on the perception of the people and thematic analysis to evaluate the experiences of the people 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 [13] 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 gas 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 and Solomon [17] 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 data presented in Table 3 show the susceptibility of residents to different ailments induced by gas flaring activities in River and Bayelsa State. The data show a gradual reduction in the number of victims exposed and currently affected by cardiovascular diseases in Rivers State. 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

Table 3. *Health challenges associated with atmospheric pollutants in area*

Location	Distance	Health challenges									
		CD	C	ND	GD	KD	LD	SD	A	B	COPD
Rivers	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
Bayelsa	200	69	44	6	333	8	3	74	12	2	15
	400	42	23	4	247	3	2	52	10	1	7
	600	26	18	3	115	3	1	36	7	0	5
	800	18	13	1	111	2	1	20	1	0	2
	1000	8	5	1	45	1	1	11	1	0	2
	2000	2	1	1	25	0	1	9	0	0	0
	Total	165	104	16	876	17	9	202	31	3	31

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. It is evident that the occurrence and exposure to gastrointestinal disorders in the place is very alarming given that a total number of 1002 persons are currently affected in following order 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. In Bayelsa State , the data show that the exposure to skin diseases is very prevalent with 74 persons at 200m, 52 persons at 400m, 36 persons at 600m, 20 persons at 800m, 11 persons at 1000m, and 9 persons at 2000m. Evidently, there is a substantial reduction in the number of residents exposed to skin diseases with increasing distance away from the flare point. This pattern with skin diseases is also replicated for the cases of asthma where more persons are exposed at the interval of 200m, with no case reported at 2000m from the gas flaring point. The exposure to COPD also show more cases close to the flare point with 15 cases at 200m and no case was recorded in residencies at the interval of 2000m away from the flare point. This study found positive correlation between the health challenges in the communities around the gas flaring sites in Rivers and Bayelsa States and the prolonged emission of pollutants from gas flaring activities. All the pollutants showed correlation with the medical ailments under investigation, 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. [18] 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 and Bayelsa states 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 activeness given the nexus between sound public health and economic viability in communities. The outcome of this study is consistent with Alimi & Gibson [19] that holds that exposure to $PM_{2.5}$ could induce chronic and adverse respiratory problems for communities. Alimi & Gibson [19] assert that the exposure to $PM_{2.5}$ that is above the limit of the WHO and can cause diseases to the cardiovascular and respiratory system, and this could provoke stroke, lung cancer and COPD. Alimi & Gibson [19] 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 [13] 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 [13]. A similar study by Ndinwa et al. [20] 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

Table 4. *ANOVA summary of the spatial variation in atmospheric pollutants across the study area*

Pollutants	Mean values		F-values	Sig
	Rivers	Bayelsa		
CO (PPM)	244.2667	242.9333	08.1310	*0.00
NO_2 (PPM)	208.0778	205.5778	09.0114	*0.02
O_3 (PPM)	173.9889	180.6556	06.2114	*0.05
SO_2 (PPM)	0.1000	0.1000	1.0211	0.21
CH_4 (PPM)	114.8556	107.1889	06.1321	*0.23
VOC (PPM)	165.0867	173.0867	17.2131	*0.03
H_2S	20.1011	23.2678	09.3112	*0.01
PM2.5 (µg/m^3)	4.2467	4.1133	12.8230	*0.00
**significant at 5% alpha level, n=30				

Table 5. *ANOVA summary of the spatial variation in health challenges within the gas flared sites in the area*

Location	Diseases	Mean values (Distance)						F-values	Sig
		200(m)	400(m)	600(m)	800(m)	1000(m)	2000(m)		
Rivers	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
Bayelsa	CD	69.1110	42.2113	26.2113	18.2113	8.2214	2.0101	10.4011	*0.00
	C	44.1110	23.2113	18.2113	13.2113	5.2214	1.0101	12.3099	*0.00
	ND	6.1110	4.0210	3.0210	1.0210	1.0311	1.0101	8.3100	*0.00
	GD	333.1110	247.0210	115.0210	111.0210	45.0311	25.0101	13.3209	*0.00
	KD	8.1110	3.0210	3.0210	2.0210	1.0311	0.0101	9.2199	*0.00
	LD	3.1110	2.0210	1.0210	1.0210	1.0311	1.0101	5.3299	*0.00
	SD	74.0121	52.0121	36.0121	20.00	11.0101	9.0101	8.8109	*0.00
	A	12.0121	10.0121	7.0121	1.0101	1.0101	0.0101	9.4199	*0.00
	B	2.0121	1.0121	0.0121	0.0101	0.0101	0.0101	10.1009	*0.00
	COPD	15.0121	7.0121	5.0121	2.0101	2.0101	0.0101	14.1198	*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

different sicknesses among residents. The residents complained of excessive heat radiation and very high temperature.

The data presented in Table 4 show the outcome of analysis of variance on the variation in the concentration of pollutants between Bayelsa and Rivers State. ANOVA show that the mean difference for carbon monoxide is between the two sampled states is significant at the $P<0.05$ level. F=08.1310, 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 carbon monoxide across the three zones in the two states in different gas flaring locations. The concentration of nitrogen oxide show statistical significant F=09.0114, sig = 0.02, ozone F=09.0114, sig = 0.05, Sulphur oxide did not show variation across the sampled locations in the two states (F=1.0211, sig = 0.02), this is because the outcome of the ANOVA analysis which is 0.21 is above the p value of 0.05. The concentration of methane show that there is not variation F=06.1321, sig = 0.23 which is also above the p value of 0.05, the concentration of volatile organic compound show that there significant variation F=06.1321, sig = 0.03 which is above the p value thus reflect statistically significant variation. Hydrogen sulphide show F=09.3112, sig = 0.01 show statistically significant variation given that the outcome 0.01 is less than the p value. The concentration of PM2.5 show there is significant variation F=12.8230, sig = 0.00.

***Table 6**. The relationship between pollutants concentration and health challenges among residents in the States under investigation*

Health issues (Rivers)	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
Health issues (Bayelsa)	**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	*0.39	0.17	*0.28	*0.21	*0.36	*0.39	*0.37	*0.60
C	*0.57	*0.26	*0.29	*0.58	*0.47	*0.45	*0.62	*0.40
ND	*0.23	*0.41	*0.37	*0.31	*0.28	*0.37	*0.56	*0.67
GD	*0.42	*0.26	*0.27	*0.29	*0.42	*0.26	*0.29	*0.47
KD	*0.26	*0.43	*0.61	*0.42	*0.31	*0.42	*0.47	*0.61
LD	*0.33	*0.56	*0.34	*0.64	*0.36	*0.23	*0.41	*0.43
SD	*0.46	0.17	0.16	*0.66	*0.34	*0.21	*0.67	*0.61
A	*0.44	*0.35	*0.30	*0.32	*0.48	*0.40	*0.30	*0.59
B	*0.24	0.20	*0.71	0.18	*0.37	*0.31	*0.41	*0.44
COPD	*0.28	0.16	*0.42	*0.36	*0.58	*0.52	*0.73	*0.37

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 result presented in Table 5 show the outcome of analysis of variance on the health challenges experienced at different intervals from the gas flaring station in Rivers and Bayelsa 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 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 COPD F=32.21979, sig = 0.00. Similarly, ANOVA also show that the mean difference for cardiovascular diseases at different intervals from the gas flaring site in Bayelsa state is significant at the P<0.05 level. F=10.4011, 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 Bayelsa state. The case of cancer F=12.3099, sig = 0.00, neurological disorders F=8.3100, sig = 0.00, gastrointestinal disorders F=13.3209, sig = 0.00, kidney diseases F=, sig = 0.00, liver diseases F=5.3299, sig = 0.00, skin diseases F=8.8109, sig = 0.00, asthma F=9.4199, sig = 0.00, bronchitis F=10.1009, sig = 0.00, and COPD F=14.1198, sig = 0.00.

The data presented in table 6 show the relationship between the concentration of pollutants and health challenges in both States. The intention of the hypothesis was to find out the extent to which the occurrences of different ailments are induced by the volume of pollutants from gas flaring sites in Rivers and Bayelsa states. In 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, bronchitis 0.49 and COPD 0.29 is significant at p<0.05. Evidently, 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 $PM_{2.5}$ and the health challenges also showed positive correlation. Similarly, he relationship between nitrogen oxide and cardiovascular diseases show positive correlation is 0.17, cancer 0.26, neurological disorders 0.41, gastrointestinal disorders 0.26, kidney diseases 0.43, liver diseases 0.56, skin diseases 0.17, asthma 0.35, bronchitis 0.20 and COPD. 0.16 is Significant at p<0.05. Evidently, all the concentration of carbon monoxide and nitrogen oxide 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 $PM_{2.5}$ and the health challenges also showed positive correlation.

Conclusions

The burning of gas from oil wells is common practice in oil producing developing countries and given the fact that economic interest is uppermost for government and the oil and gas companies operating in the region, the environmental and health consequences of the prolonged emission of toxins into the communities is treated with laxity. This study revealed that Rivers and Bayelsa States are heavily polluted with the prolonged gas flaring activities and the people living close to the flare points are more vulnerable to health challenges such as cardiovascular diseases, cancer, neurological disorders, gastrointestinal disorders, kidney diseases, liver diseases, skin diseases, asthma, bronchitis and COPD. Consequently, reduction in the quantity of gas flared, enactment of laws prohibiting residential and farming activities within 4km of the circumference of gas flaring sites, collaborative efforts between governments and NGO's to provide health education and sensitization on impacts of gas flaring for the communities, insistence on environmentally friendly technologies in operations of oil companies and zero tolerance for defaulting companies on the regulations and laws on flaring of gases were topmost on the recommendation list.

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