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UNDERSTANDING POLLUTANT DISPERSION PATTERN IN RESPONSE TO DIURNAL ATMOSPHERIC DYNAMICS AROUND GAS POWER PLANTS STATIONS IN SOUTH-SOUTH REGION

Nwankwo, Promise Chibuzo[1], Kpang, MeeluBari Barinua Tsaro[2*], Dappa, Daddy Ibiewotogha[3]

[1-2-3] Department of Geography and Environmental Management, Faculty of Social Sciences, University of Port Harcourt, Port Harcourt, Nigeria

Corresponding Author Kpang, MeeluBari Barinua Tsaro

Department of Geography and Environmental Management, Faculty of Social Sciences, University of Port Harcourt, Port Harcourt, Nigeria

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Abstract: Air pollution is a major environmental challenge plaguing our society in recent time and raises global concern because of its devastating consequences on public health and the environment. Despite availability of environmental policies and air quality standards, this issue seems unabated as the sources of air pollution in the area increases almost on a daily basis arising from different human activities including electricity generation from power plants. This study examined pollutants dispersion pattern due to atmospheric changes around gas power plants in south-south region. Air quality samples were obtained in-situ around the gas plant stations at various calibrated distances, 200, 400, 600, 800 and 1000m in the morning, afternoon and evening, each day at the sampled location over a period of 6 months (January to June), The main gases measured at each of the sampled locations and at different times of the day include Sulfur dioxide (SO_2), Nitrogen oxides (NO_X), Particulate matter (PM), Carbon dioxide (CO_2), Methane (CH_4), Carbon monoxide (CO), Hydrogen Sulphide (H_2S), Ozone (O_3) and Volatile Organic Compound (VOC). Descriptive statistics (standard deviation and means) were used to summarize the data measured. The student t test statistic was employed for the analysis. There was a significant difference in the pollutant concentration at the different times of the day at $p<0.05$ and the data showed that the early hours of the day had less pollutants concentration than at evening hours. There was also a significant difference in the pollutant concentration observed in the region as compared with the WHO standards. The study recommended periodic environmental auditing, reforestation, discouragement of deforestation within the vicinity of gas plants and constant air quality monitoring.

Keywords: Air quality, Diurnal, Dynamics, Dispersion, Atmospheric.

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INTRODUCTION

Air pollution can be defined as a situation in which substances are present in the atmosphere at concentration sufficiently high above their normal ambient levels to produce a measurable and undesirable effect on humans, animals, vegetation, or materials (Mbachu, 2020). The concentrations of pollutants in the atmosphere are a measure of air quality. The United Nations Development Programme (UNDP) (2006) estimates that exposure to ambient air pollution causes approximately 3.7 million premature deaths worldwide each year. Under a business-as-usual socioeconomic scenario, it has been stated that the contribution of outdoor air pollution to worldwide premature mortality by 2050 could double Njoku, Ogunsola & Oladiran (2019) and that air pollution will be the top environmental cause of premature mortality (UNDP, 2006). Depending on the exposure, the effects of air pollution on human health range from subclinical and symptomatic events to increased morbidity and mortality (Obiekezie, & Agbo, 2008). The acute and chronic exposure to air pollutants – gases and aerosols – has been positively associated with respiratory and cardiovascular sicknesses, and lung-cancer (Zabbey, Sam, Newsom, & Nyiaghan, 2021). Over the years, various chemicals have been emitted into the air from natural and anthropogenic sources in Nigeria and other developing leading to progressive degradation in air quality particularly industrialization, urbanization, lack of awareness, increasing number of motor vehicles, use of fuels with poor environmental performance, badly maintained roads and ineffective environmental regulation. This has increased the awareness about possible biological effects of deposition of various pollutants in the atmospheric environment principally because atmospheric pollution poses significant impact both to human health and the environment (Odigure & Abdulkareem, 2001). Additionally, another major source of air pollution apart from the rapid oxidation or burning of crude oil-associated with natural gas that releases gaseous, particulate, and heat matter into the atmosphere with negative impacts on ecosystem and health of residents in such vicinity is the power plants (Nelson, 2012).

Power generation plant is a facility designed to produce electric energy from another form of energy, most power plants use one or more generators that convert mechanical energy into electrical energy in order to supply power to the electrical grid for society's electrical needs. In the process of converting mechanical energy into electrical energy in order to supply power to the electrical grid for society’s electrical needs, air quality of the vicinity is polluted. Air pollutants from power plant stations creates emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_X), particulate matter (PM), carbon dioxide (CO_2), mercury (Hg), and other pollutants. Studies have shown that air pollution in the vicinity of gas plants can harm when it accumulates in the air in high enough concentrations. People exposed to high enough levels of certain air pollutants may experience: irritation of the eyes, nose, and throat, wheezing, coughing, chest tightness, and breathing difficulties, worsening of existing lung and heart problems, such as asthma, increased risk of heart attack. In addition, long-term exposure to air pollution can cause cancer and damage to the immune, neurological, reproductive, and respiratory systems and in extreme cases, it can even cause death. Recently, several European studies have highlighted that there are statistically significant positive associations between Nitrogen dioxide (NO_2) and Sulphur dioxide (SO_2) concentrations with total, cardiovascular and respiratory mortality, particularly in urban areas (Okoro, Adeleye, Okoye & Maxwell, 2021). Long-term exposure to tropospheric ozone (O_3) and particulate matter (PM) has also been linked with increased death risk due to cardiopulmonary causes (Chimezie, 2020). On the other hand, O_3 is responsible for 17400 premature deaths each year (UNDP, 2006). The degradation of air also results in an increase of the burden of other related diseases, a reduction in life expectancy, and an increase in the health care public spending which convey to air pollution considerable financial and life quality costs (Fagbeja, Chatterton, Longhurst, Akinyede & Adegoke, 2008).

Everywhere in the world whether in Europe, America, Asia or Africa continents, proximity to natural gas power plants has been linked to increased air pollution levels within the landscape, which can have detrimental effects on respiratory health of the residents. Evidence of higher levels of nitrogen oxides (NOx), volatile organic compounds (VOCs), and particulate matter (PM) in the vicinity of natural gas power plants is reported in studies such as Ragothaman & Anderson, (2017), Turnock et al. (2016), Lurmann *et al*. (2015) & Mackie *et al*. (2016) that air pollutants emitted from this facility are known to be harmful to human health and the environment as the power plant emit annually over 200 tons of particulate matter, over 300 tons of nitrogen oxides and over 100 tons of volatile organic compounds (VOCs) (World Health Organization, 2017). The National Institute for Occupational Safety & Health (2021), a federal agency of the United States responsible for conducting research and making recommendations for the prevention of work-related injury and illness identified that gas plant stations air quality problems develop from a number of factors. In the urban climate various kinds of emission sources are concentrated; pollutants emitted from them mix with the ambient air so that a polluted air mass covers the urban area and disperses into suburban and rural areas in its lee. The air quality of power plant station is a result of the interaction between the outdoor environment, climate, plant structure, construction techniques, contaminant sources (activities within the power plant station and moisture, processes and activities within the power plant station), and the burning of fossil fuels, such as coal, oil and natural gas. Rajput & Agrawal (2005) posit that air pollutants can travel long distances and cause impacts far from its source. Based on this assumption, it was necessary to understand the dispersion pattern of pollutants load in the vicinity of gas power plant stations amidst changing atmospheric conditions.

MATERIALS AND METHODS

The South-South region is located in the Niger Delta region of Nigeria and lying between latitudes 3°25'30"N – 8°28'30"N and longitudes 5°10'0"E – 9°22'30"E). It is one of the six geopolitical zones in Nigeria, signifying both the geographic and political districts of east coast of Nigeria and traverses through the Atlantic coast from the Benin Bay coast in the west to the Bonny Bay coast in the east. The ecosystem of the area is highly diverse and supportive of numerous species of terrestrial and aquatic flora and fauna and human life. The region has the largest mangrove swamps in Africa, with its stagnant swamp covering about 8600 squares, and about 2,370 square kilometers of the area consist of estuaries, creeks and rivers. It comprises of over 70,000km^2 and constitutes about 7.5% of Nigeria's land mass. The monsoon wet (rainy) season over the area begins in May, as a result of the seasonal northward movement of the Intertropical Convergence Zone (ITCZ) and terminates in October with a total annual rainfall varying from 2400mm to 4000mm within West Africa (Myers *et al*., 2010). The region is swayed by the localized convection of the West African monsoon with less contribution from the mesoscale and synoptic system of the Sahel (Thomas & Baltzer, 2002). The region is dominated by mining activity (petroleum) and has about 70% of its population living in rural areas. The study was carried out within the vicinity of gas plant stations in the six city centres in the south-south states and the gas plants around which air quality investigation were measured are; Rivers (Afam Gas Plant), Bayelsa (Gbarain Gas Plant), Delta (Okpai Gas Plant), Akwa Ibom (Ibom Gas Plant), Cross River (Cross River Gas Plant) and Edo (Edo Gas Plant) respectively. Air quality samples were obtained in-situ around the gas plant stations at various calibrated distances, 200, 400, 600, 800 and 1000 meters from the centroid of the gas plant stations in the windward direction. Air quality sampling were carried out in the morning, afternoon and evening, each day at the sampled location over a period of 6 months (January to June), 2024 in line with the UK Environmental Agency, (2011) and analyzed in-situ with potable air measurement equipment and the averages recorded for necessary statistical analysis. The need to do the measurements for a period of six (6) months was to establish the seasonal variation in the gas distribution in the area. The following pollutant parameters were measured using potable in-situ direct reading instruments and at a sampling height of 2m: Sulfur dioxide (SO_2), nitrogen oxides (NOX), particulate matter ($PM_{2.5}$), carbon dioxide (CO_2). A digital hand-held probe (Hold Peak 1aser PM – meter-HP 58001D ZheliarJida Hupau Instrument Company Limited, China) which houses a laser optical sensor for detecting and measuring particulate concentrations up to 1 milligram per cubic meter was used for measuring ($PM_{2.5}$). The Industrial Scientific Corporation ITX Multigas-Gas monitor was used for the detection and measurement of Nitrogen oxide (NO_2), Sulphur Oxides (SO_2), and volatile organic compounds (VOCs). Additionally, the analysis was done using the one way student –t test statistics.

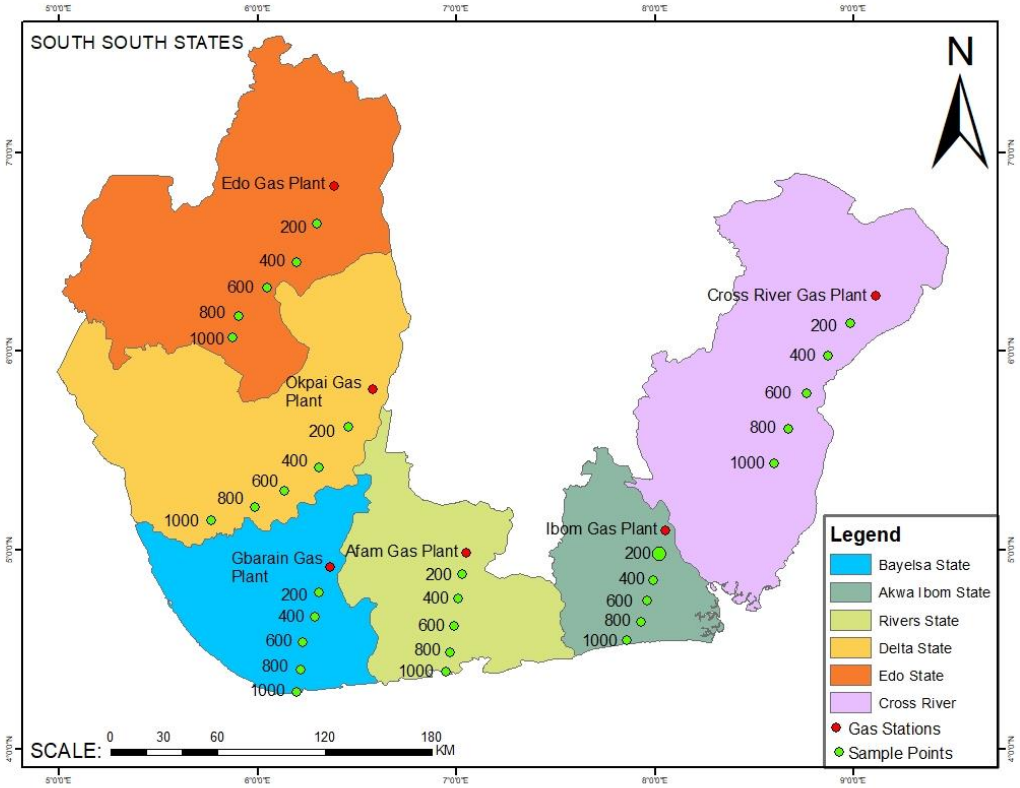

Figure 1: South-South States and Air Quality Sampled locations

Discussion of Results

Table 1: Pollutant concentration at different times of the day in Port Harcourt

Months	Time of day	CO (PPM)	NO_2 (PPM)	O_3 (PPM)	SO_2 (PPM)	$PM_{2.5}$ ($\mu g/m^3$)	CH_4 (PPM)	VOC (PPM)	H_2S (PPM)
January	Morning	255	208.3	188.9	0.1	110.6	184.8	32.6	4.18
	Afternoon	292.3	228.7	202.7	0.1	126.8	196.3	36	4.86
	Evening	264.5	206.4	187.7	0.1	110	190.66	37	4.7
February	Morning	233	203.3	183.9	0.1	105.5	172.8	25.6	3.98
	Afternoon	277.3	222.7	195.7	0.1	120	187.3	25.9	4.56
	Evening	258.5	201.4	179.7	0.1	106	183.66	28	4.6
March	Morning	209	197.3	177.9	0.1	98.5	162.8	19.6	3.88
	Afternoon	267.3	219.7	190.7	0.1	114	179.3	18.54	4.36
	Evening	252.5	196.4	171.7	0.1	102	176.66	18	4.5
April	Morning	188	193.3	174.9	0.1	94.5	154.8	16.2	3.58
	Afternoon	260.3	217.7	186.7	0.1	109	172.3	17.26	4.36
	Evening	248.5	192.4	164.7	0.1	99	171.66	14.76	4.4
May	Morning	178	189.3	171.9	0.1	93.5	148.8	15	3.08
	Afternoon	253.3	215.7	182.7	0.1	108.5	165.3	15.58	4.16
	Evening	244.5	188.4	157.7	0.1	98	167.66	14.08	3.8
June	Morning	168	185.3	168.9	0.1	92.5	142.8	15	3.08
	Afternoon	246.3	213.7	178.7	0.1	108	158.3	18.1	4.16
	Evening	240.5	184.4	150.7	0.1	97	163.66	15.6	3.8

WHO permissible limit 2021: CO (ppm); O_3 60 (PPM); $NO_2$10 (PPM); $SO_2$40 (PPM); VOC0.5 (PPM); $PM_{2.5}$15 ($\mu g/m^3$)

The data presented in Table 1 show the hourly and monthly concentration of pollutant load in Port Harcourt. The concentration of pollutants in the atmosphere is above the permissible limits of the World Health Organization as updated in 2021. The concentration of CO in June show more retention in the atmosphere during the afternoon and evening hours with 292.3pm and 264.5ppm respectively. Curiously, the concentration of CO (255ppm) in the morning is significantly different and lower than what was recorded in the afternoon and evening in January. The case is the same for the concentration of NO_2, O_3, $PM_{2.5}$, CH_4, VOCs, and H2S where the morning hours had less concentration of pollutant loads that the afternoon hours. It is very conspicuous that the load of SO_2 was constant during all time of the day and across all the months under investigation with 0.1ppm. The pattern recorded in January is also replicated in February, March, April, May and June. But, remarkably, the months of May and June recorded a significant reduction in pollutant loads than the previous months which can be linked to progression into the peak of the rainy season where rainfall plays a critical role in the concentration of pollutant loads in the atmosphere.

Figure 2: Pattern of Pollutant Concentration in Port Harcourt

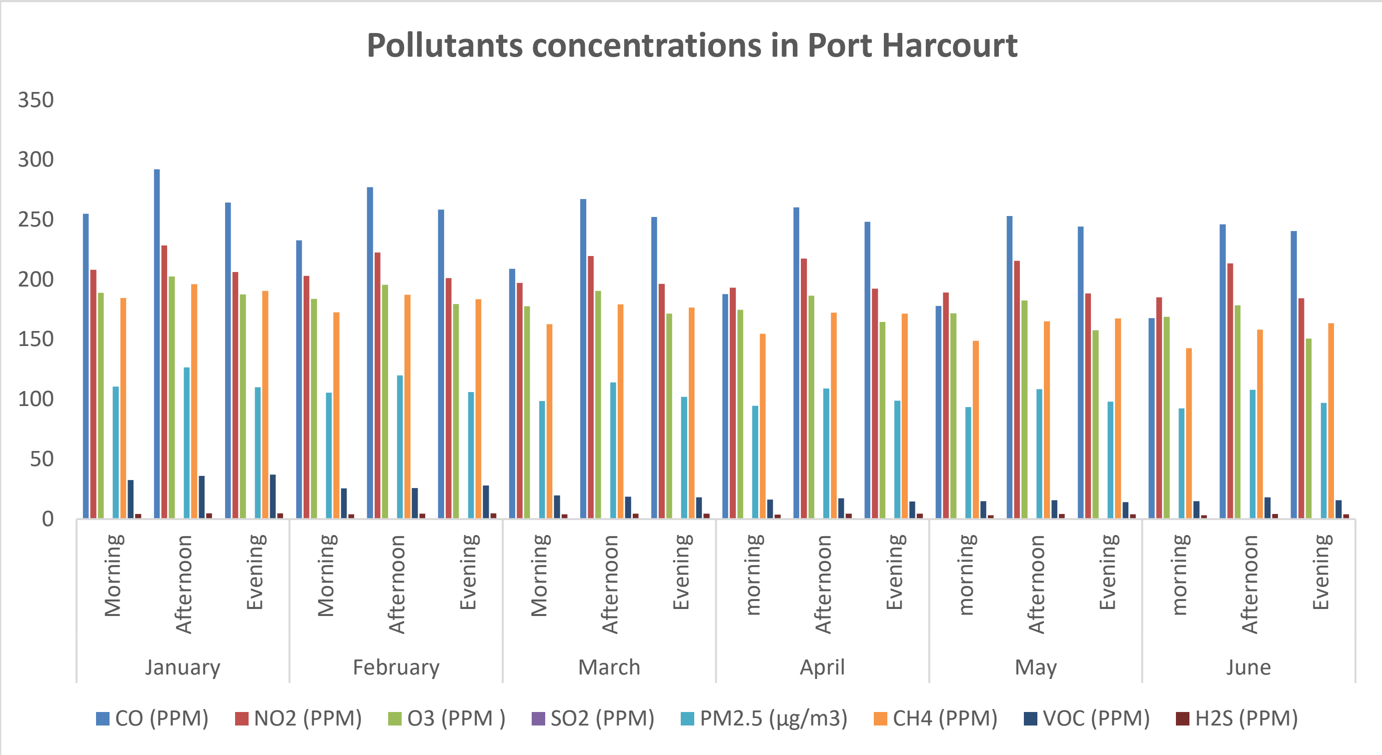

Table 2: Pollutant concentration at different times of the day in Uyo

Months	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)
January	Morning	251	203.3	184.9	0.1	108.6	181.8	31.6	4.08
	Afternoon	286.3	225.7	201.7	0.1	125.8	195.3	34	4.76
	Evening	262.5	202.4	185.7	0.1	108	188.66	36	4.6
February	Morning	229	198.3	179.9	0.1	103.5	169.8	24.6	3.88
	Afternoon	271.3	219.7	194.7	0.1	119	186.3	23.9	4.46
	Evening	256.5	197.4	177.7	0.1	104	181.66	27	4.5
March	Morning	205	192.3	173.9	0.1	96.5	159.8	18.6	3.78
	Afternoon	261.3	216.7	189.7	0.1	113	178.3	16.54	4.26
	Evening	250.5	192.4	169.7	0.1	100	174.66	17	4.4
April	Morning	184	188.3	170.9	0.1	92.5	151.8	15.2	3.48
	Afternoon	254.3	214.7	185.7	0.1	108	171.3	15.26	4.26
	Evening	246.5	188.4	162.7	0.1	97	169.66	13.76	4.3
May	Morning	174	184.3	167.9	0.1	91.5	145.8	14	2.98
	Afternoon	247.3	212.7	181.7	0.1	107.5	164.3	13.58	4.06
	Evening	242.5	184.4	155.7	0.1	96	165.66	13.08	3.7
June	Morning	164	180.3	164.9	0.1	90.5	139.8	14	2.98
	Afternoon	240.3	210.7	177.7	0.1	107	157.3	16.1	4.06
	Evening	238.5	180.4	148.7	0.1	95	161.66	14.6	3.7

WHO permissible limit 2021: CO 4(ppm); O_3 60 (PPM); $NO_2$10 (PPM); $SO_2$40 (PPM); VOC0.5 (PPM); $PM_{2.5}$15 (µg/m^3)

The data presented in Table 2 show the concentration of pollutant from gas plant in Uyo. The concentration of pollutants in the atmosphere is above the permissible limits of the World Health Organization as updated in 2021. The data show significant variation in the concentration of pollutant during the different hours of the day and across different months, the concentration of pollutant is higher in the afternoon and in the evening in Uyo. For example, O_3 had 201.7ppm and 185.7ppm in the afternoon and evening respectively, but the concentration of O_3 in the morning us 184.9ppm. The concentration of SO_2 is constant in all times of the day and in all the months. Expectedly, the months of May and June recorded slight reduction in pollutant loads which can be adduced to the influences of meteorological parameters such as rainfall and temperature.

Figure 3: Pattern of Pollutant Concentration in Uyo

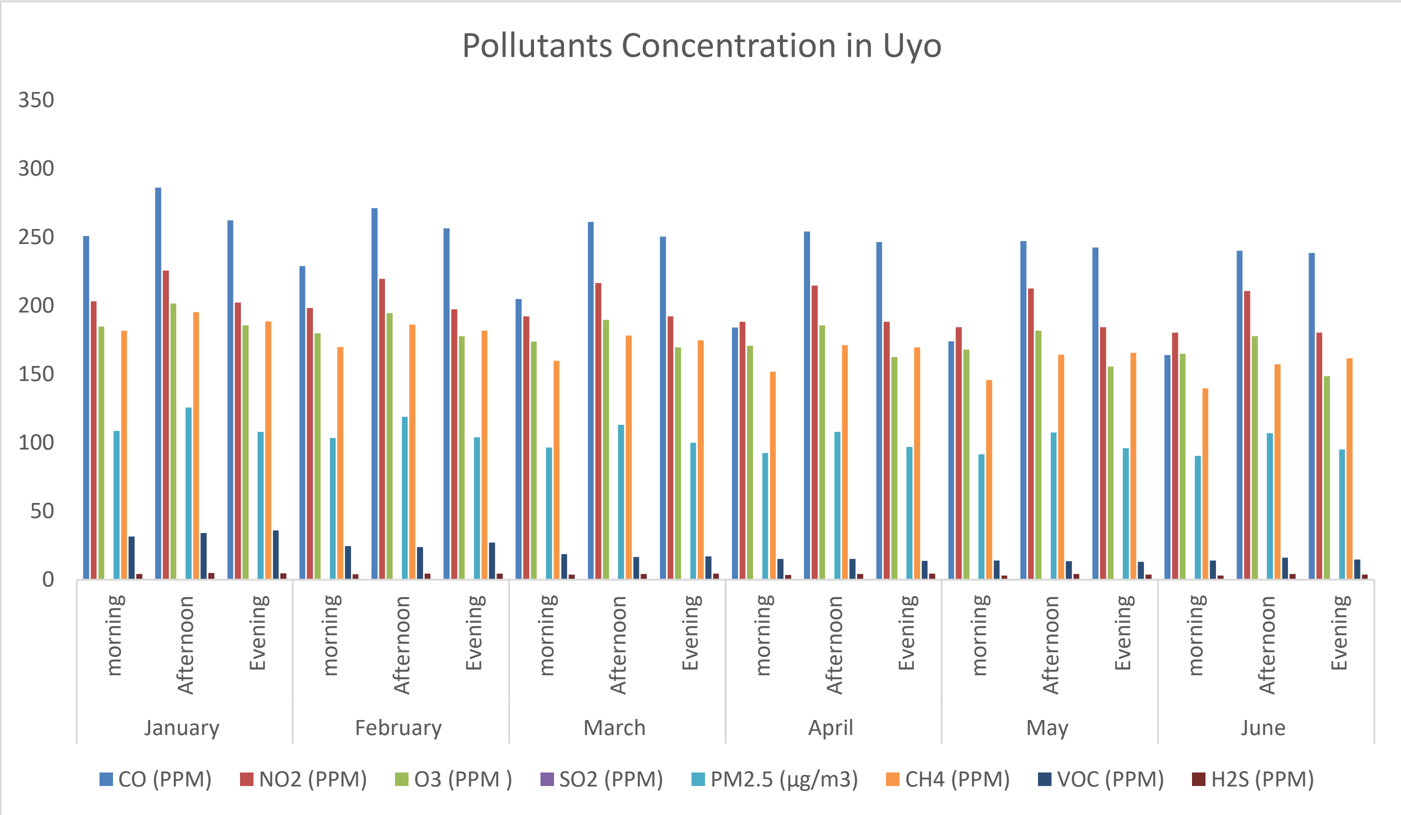

Table 3: Pollutant concentration at different times of the day in Calabar

Months	Time of day	CO (PPM)	NO_2 (PPM)	O_3 (PPM)	SO_2 (PPM)	$PM_{2.5}$ ($\mu g/m^3$)	CH_4 (PPM)	VOC (PPM)	H_2S (PPM)
January	Morning	247	198.3	180.9	0.1	105.6	178.8	30.6	3.98
	Afternoon	279.3	222.7	200.7	0.1	124.8	194.3	32	4.66
	Evening	259.5	198.4	183.7	0.1	104	186.66	35	4.5
February	Morning	225	193.3	175.9	0.1	100.5	166.8	23.6	3.78
	Afternoon	264.3	216.7	193.7	0.1	118	185.3	21.9	4.36
	Evening	253.5	193.4	175.7	0.1	100	179.66	26	4.4
March	Morning	201	187.3	169.9	0.1	93.5	156.8	17.6	3.68
	Afternoon	254.3	213.7	188.7	0.1	112	177.3	14.54	4.16
	Evening	247.5	188.4	167.7	0.1	96	172.66	16	4.3
April	Morning	180	183.3	166.9	0.1	89.5	148.8	14.2	3.38
	Afternoon	247.3	211.7	184.7	0.1	107	170.3	13.26	4.16
	Evening	243.5	184.4	160.7	0.1	93	167.66	12.76	4.2
May	Morning	170	179.3	163.9	0.1	88.5	142.8	13	2.88
	Afternoon	240.3	209.7	180.7	0.1	106.5	163.3	11.58	3.96
	Evening	239.5	180.4	153.7	0.1	92	163.66	12.08	3.6
June	Morning	160	175.3	160.9	0.1	87.5	136.8	13	2.88
	Afternoon	233.3	207.7	176.7	0.1	106	156.3	14.1	3.96
	Evening	235.5	176.4	146.7	0.1	91	159.66	13.6	3.6

WHO permissible limit 2021: CO4 (ppm); O_3 60 (PPM); $NO_2$10 (PPM); $SO_2$40 (PPM); VOC0.5 (PPM); $PM_{2.5}$15 ($\mu g/m^3$)

The data presented in Table 3 show the hourly and monthly concentration of pollutants loads in Calabar. The concentration of pollutants in the atmosphere is above the permissible limits of the World Health Organization as updated in 2021. The outlook of the data show similarity with the case in Port Harcourt and Uyo in the region. For example, the constancy of SO_2 which is 0.1pppm across all the period of the day and in all the months under investigation. The concentration of $PM_{2.5}$ in January show higher concentration in the morning and in the afternoon with 105.6 and 124.8ppm respectively, this is a deviation from the previous pattern in Uyo and Port Harcourt. It is also very conspicuous that the months of January, March and April had higher concentration of pollutant than May and June.

Figure 4: Pattern of Pollutant Concentration in Calabar

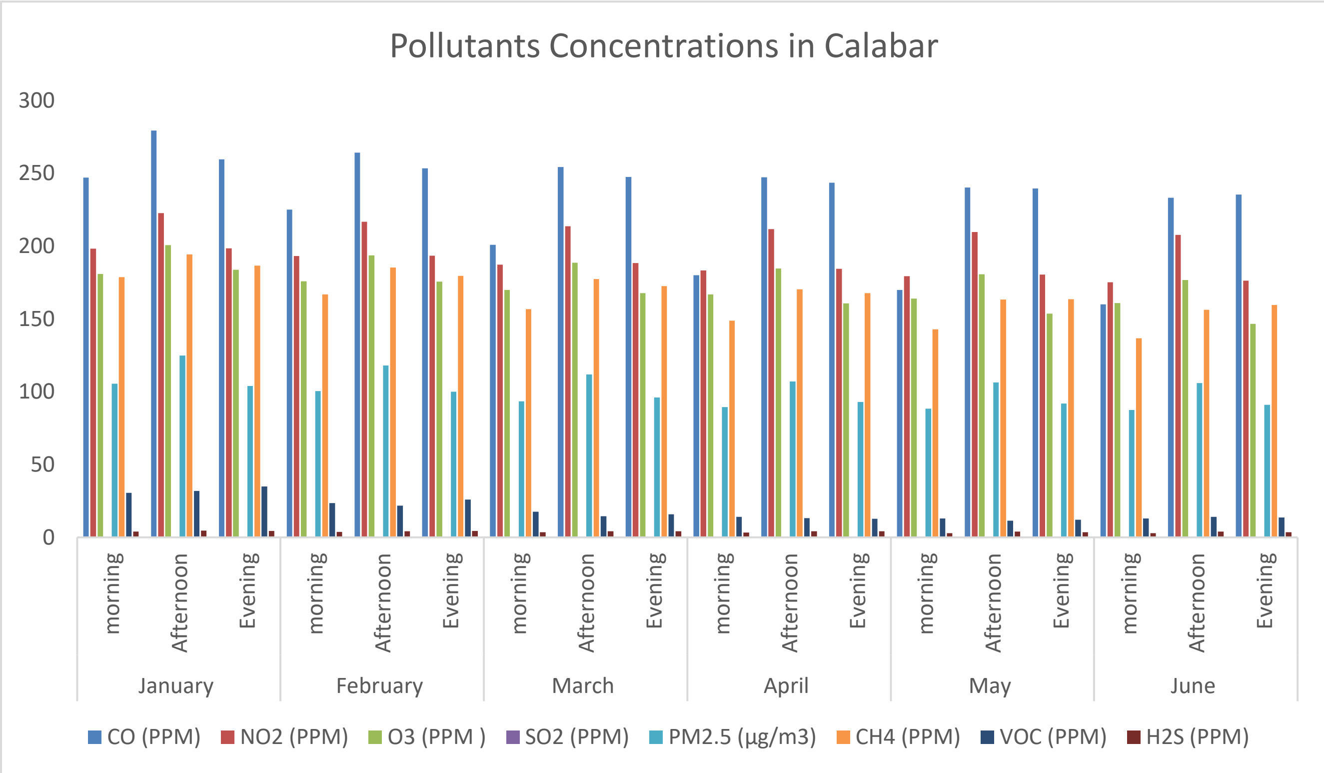

Table 4: Pollutant concentration at different times of the day in Yenagoa

Months	Time of day	CO (PPM)	NO_2 (PPM)	O_3 (PPM)	SO_2 (PPM)	$PM_{2.5}$ ($\mu g/m^3$)	CH_4 (PPM)	VOC (PPM)	H_2S (PPM)
January	Morning	255	211.8	183.9	0.1	118.6	179.8	30.6	4.18
	Afternoon	300.3	237.2	198.7	0.1	143.8	188.3	35.5	5.16
	Evening	266.5	207.9	182.7	0.1	114	185.66	36	4.8
February	Morning	233	206.8	178.9	0.1	113.5	167.8	23.6	3.98
	Afternoon	285.3	231.2	191.7	0.1	137	179.3	25.4	4.86
	Evening	260.5	202.9	174.7	0.1	110	178.66	27	4.7
March	Morning	209	200.8	172.9	0.1	106.5	157.8	17.6	3.88
	Afternoon	275.3	228.2	186.7	0.1	131	171.3	18.04	4.66
	Evening	254.5	197.9	166.7	0.1	106	171.66	17	4.6
April	Morning	188	196.8	169.9	0.1	102.5	149.8	14.2	3.58
	Afternoon	268.3	226.2	182.7	0.1	126	164.3	16.76	4.66
	Evening	250.5	193.9	159.7	0.1	103	166.66	13.76	4.5
May	Morning	178	192.8	166.9	0.1	101.5	143.8	13	3.08
	Afternoon	261.3	224.2	178.7	0.1	125.5	157.3	15.08	4.46
	Evening	246.5	189.9	152.7	0.1	102	162.66	13.08	3.9
June	Morning	168	188.8	163.9	0.1	100.5	137.8	13	3.08
	Afternoon	254.3	222.2	174.7	0.1	125	150.3	17.6	4.46
	Evening	242.5	185.9	145.7	0.1	101	158.66	14.6	3.9

WHO permissible limit 2021: CO4 (ppm); O_3 60 (PPM); $NO_2$10 (PPM); $SO_2$40 (PPM); VOC0.5 (PPM); $PM_{2.5}$15 ($\mu g/m^3$)

The data on hourly and monthly concentration of pollutant loads in Yenagoa is presented in Table 4 The concentration of pollutant loads from gas power plant is higher than the permissible limits of the World Health Organization (WHO) across all the months under investigation. For example, the limit of the Who for VOC is 0.5ppm whereas the minimum VOC recorded in Yenagoa is 13ppm. Evidently, the concentration of SO_2, is constant throughout all the months from January to June, and in different hours of the day with 0.1ppm. This is different for CO where less concentration is recorded in the morning (255ppm) than in the afternoon (300.3ppm) and evening (266.5ppm). The concentration of pollutant in the dry and rainy season also show remarkable variation given that the dry season months recorded higher pollutant load in Yenagoa.

Figure 5: Pattern of Pollutant Concentration in Yenagoa

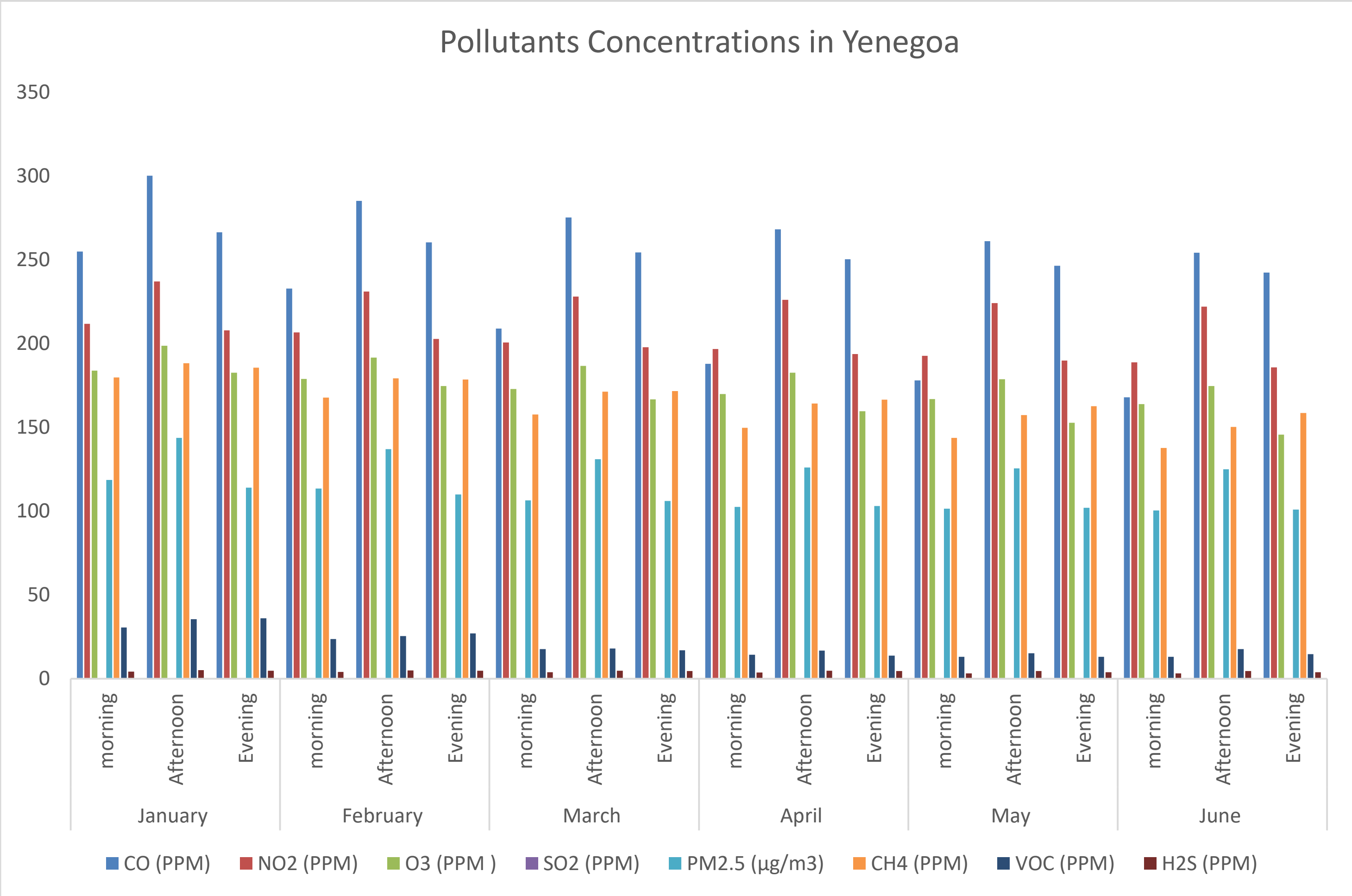

Table 5: Pollutant concentration at different times of the day in Benin

Months	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)
January	Morning	255	211.8	183.9	0.1	118.6	179.8	30.6	4.18
	Afternoon	300.3	237.2	198.7	0.1	143.8	188.3	35.5	5.16
	Evening	266.5	207.9	182.7	0.1	114	185.66	36	4.8
February	Morning	233	206.8	178.9	0.1	113.5	167.8	23.6	3.98
	Afternoon	285.3	231.2	191.7	0.1	137	179.3	25.4	4.86
	Evening	260.5	202.9	174.7	0.1	110	178.66	27	4.7
March	Morning	209	200.8	172.9	0.1	106.5	157.8	17.6	3.88
	Afternoon	275.3	228.2	186.7	0.1	131	171.3	18.04	4.66
	Evening	254.5	197.9	166.7	0.1	106	171.66	17	4.6
April	Morning	188	196.8	169.9	0.1	102.5	149.8	14.2	3.58
	Afternoon	268.3	226.2	182.7	0.1	126	164.3	16.76	4.66
	Evening	250.5	193.9	159.7	0.1	103	166.66	13.76	4.5
May	Morning	178	192.8	166.9	0.1	101.5	143.8	13	3.08
	Afternoon	261.3	224.2	178.7	0.1	125.5	157.3	15.08	4.46

	Evening	246.5	189.9	152.7	0.1	102	162.66	13.08	3.9
June	Morning	168	188.8	163.9	0.1	100.5	137.8	13	3.08
	Afternoon	254.3	222.2	174.7	0.1	125	150.3	17.6	4.46
	Evening	242.5	185.9	145.7	0.1	101	158.66	14.6	3.9

WHO permissible limit 2021: CO4 (ppm); O_3 60 (PPM); $NO_2$10 (PPM); $SO_2$40 (PPM); VOC0.5 (PPM); $PM_{2.5}$15 (μg/m^3)

The data presented in Table 5 show the pollutant loads from gas power plant in Benin City. The outlook during different time of the day and months show significant variation from the permissible limit set by the World health Organization. There is a similarity between Benin and other cities in the concentration of SO_2 which is 0.1ppm. But CO show less concentration in the morning in February with 233ppm when compared to the case in the afternoon (285.3ppm) in the afternoon and 260.5ppm in the evening. It is also very conspicuous that the dry season month recorded higher pollutant loads than the rainy season months in Yenagoa. The concentration of pollutants in the atmosphere is above the permissible limits of the World Health Organization as updated in 2021.

Figure 6: Pattern of Pollutant Concentration in Benin

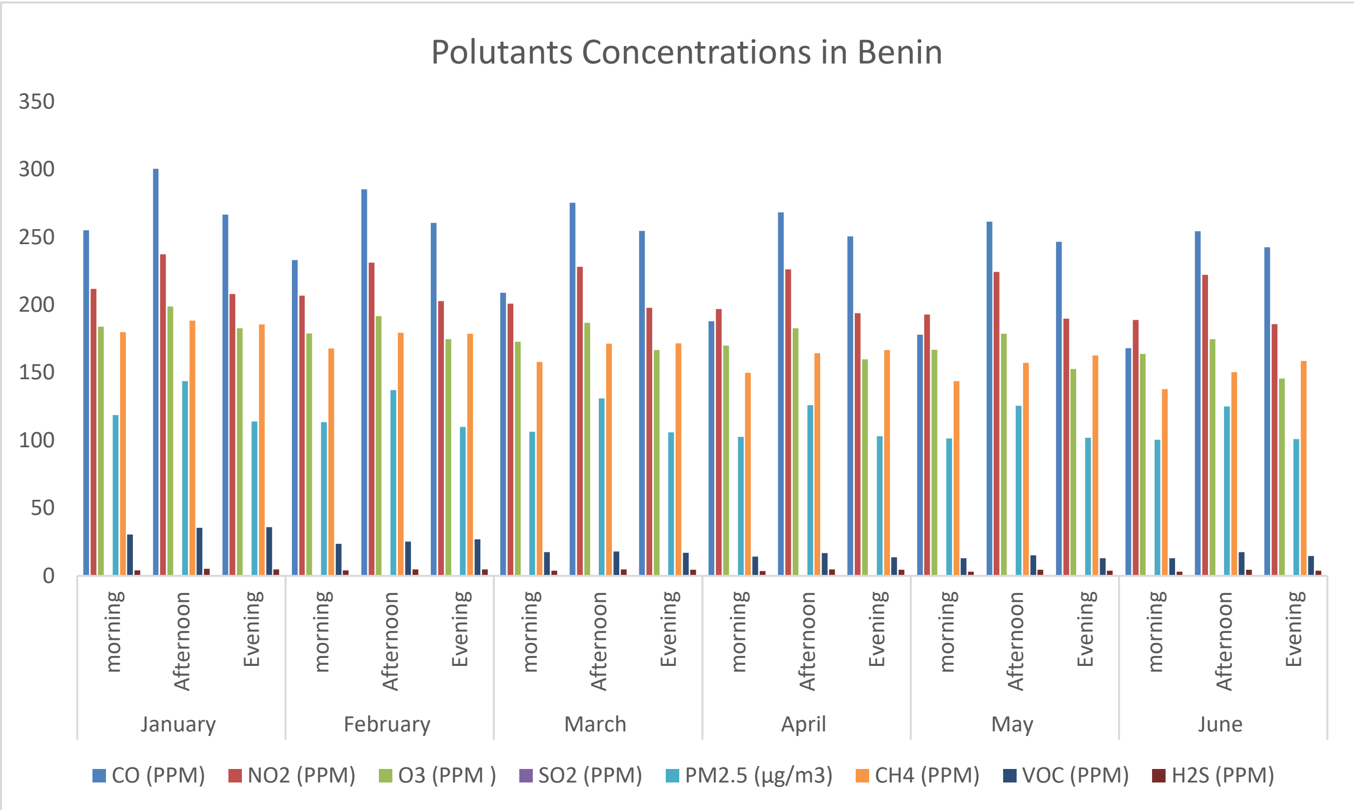

Table 6: Pollutant concentration at different times of the day in Warri

Months	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)
January	Morning	245	202.8	182.9	0.1	103.6	176.8	29.6	3.98
	Afternoon	282.3	223.2	196.7	0.1	118.8	187.3	33.5	4.76
	Evening	254.5	200.9	181.7	0.1	104	183.66	35	4.6
February	Morning	223	197.8	177.9	0.1	98.5	164.8	22.6	3.78
	Afternoon	267.3	217.2	189.7	0.1	112	178.3	23.4	4.46
	Evening	248.5	195.9	173.7	0.1	100	176.66	26	4.5
March	Morning	199	191.8	171.9	0.1	91.5	154.8	16.6	3.68
	Afternoon	257.3	214.2	184.7	0.1	106	170.3	16.04	4.26
	Evening	242.5	190.9	165.7	0.1	96	169.66	16	4.4
April	Morning	178	187.8	168.9	0.1	87.5	146.8	13.2	3.38
	Afternoon	250.3	212.2	180.7	0.1	101	163.3	14.76	4.26
	Evening	238.5	186.9	158.7	0.1	93	164.66	12.76	4.3

May	Morning	168	183.8	165.9	0.1	86.5	140.8	12	2.88
	Afternoon	243.3	210.2	176.7	0.1	100.5	156.3	13.08	4.06
	Evening	234.5	182.9	151.7	0.1	92	160.66	12.08	3.7
June	Morning	158	179.8	162.9	0.1	85.5	134.8	12	2.88
	Afternoon	236.3	208.2	172.7	0.1	100	149.3	15.6	4.06
	Evening	230.5	178.9	144.7	0.1	91	156.66	13.6	3.7

WHO permissible limit 2021: CO4 (ppm); O_3 60 (PPM); $NO_2$10 (PPM); $SO_2$40 (PPM); VOC0.5 (PPM); $PM_{2.5}$15 (µg/m^3)

The data presented in Table 6 show the pollutant loads from gas power plant in Warri. The data show that the pollutant loads in the city is higher than the limit set by the World Health Organization in all the months. The constancy of SO_2 (0.1ppm) is replicated in Warri. But the month of June which is in the rainy season show a significant reduction in the concentration of H_2S in the morning with 2.88ppm. The case for May in the rainy season shows that CO is 168ppm in the morning, 243.3ppm in the afternoon and 234.5ppm in the evening hours. This pattern is very prevalent across all the months. The concentration of pollutants in the atmosphere is above the permissible limits of the World Health Organization as updated in 2021.

Figure 7: Pattern of Pollutant Concentration in Warri

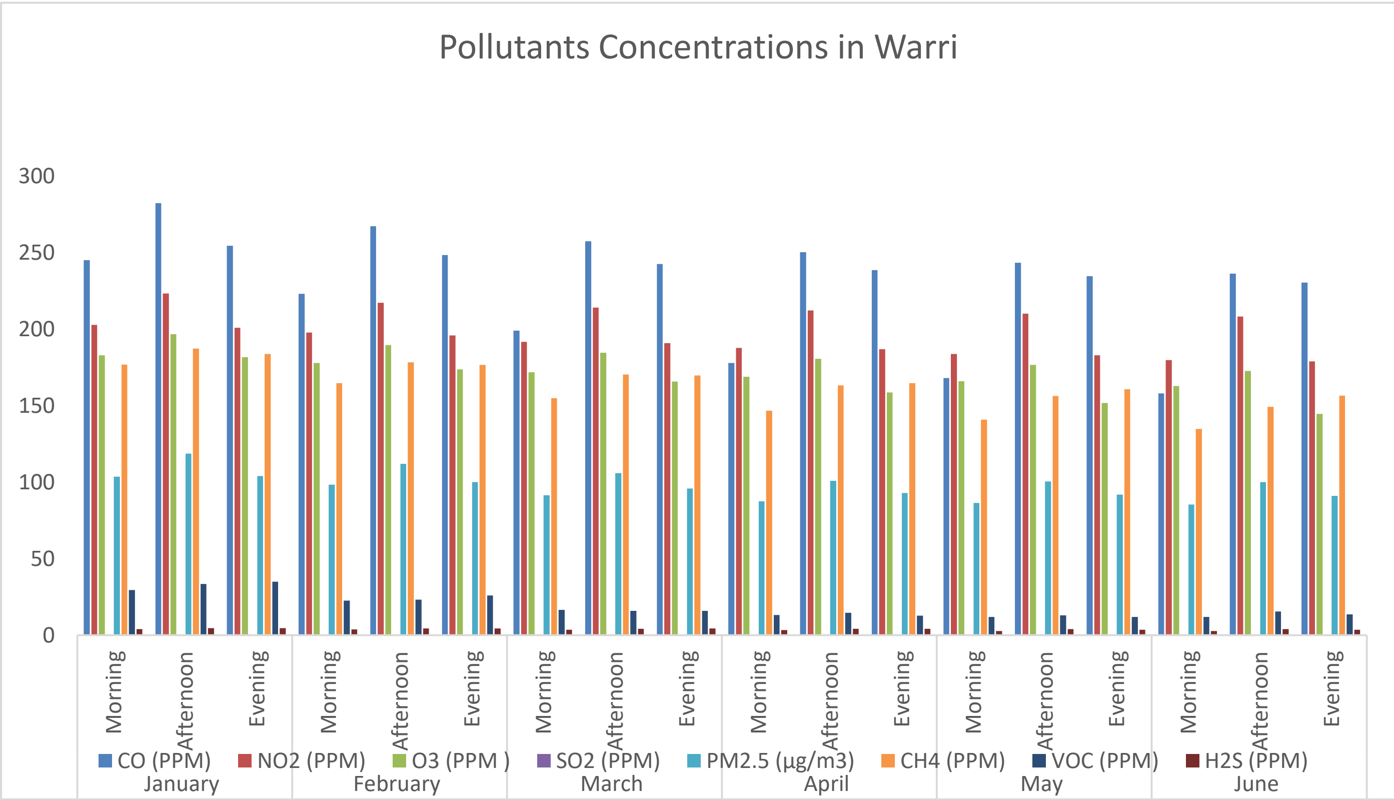

Table 7: One sample t test summary for comparing atmospheric pollutants measured in the area with the World Health Organisation standards

Gases	Locations						Df	Sig	Test value	Decision
	PH	Uyo	Calabar	Yenagoa	Benin	Warri				
	T	t	t	t	T	t				
CO	242.7	232.9	228.3	242.7	240.3	229.4	181	.000	60 (PPM)	Significant
O_3	121.6	116.3	114.0	121.6	114.0	115.4	181	.000	10 (PPM)	Significant
NO_2	198.7	189.6	185.6	198.7	198.1	187.3	181	.000	40 (PPM)	Significant
SO_2	-39.9	-39.9	-39.9	-39.9	-39.9	-39.9	181	.000	0.5 (PPM)	Significant
VOC	22.2	19.4	18.1	22.2	19.6	18.3	181	.000	15 (µg/m^3)	Significant
$PM_{2.5}$	93.1	88.5	85.9	93.1	99.9	83.9	181	.000	4 (ppm)	Significant

Methane and H2S are not captured in the WHO AQG (2021)

The data presented in Table 7 show the outlook of pollutant load as compared to the permissible limit of the World Health Organization (WHO) in the area under investigation (Port-Harcourt, Uyo, Calabar, Yenagoa, Benin and Warri). The outcome of t-test computation shows that the variation in the concentration of CO, O_3, NO_2, SO_2, VOC and $PM_{2.5}$ is significant at df: 181, sig 0.000. The concentration of H2S and CH4 is not captured in the updated WHO AQG (2021) and thus variation cannot be verified. The outcome of the analysis validates the alternate hypotheses which states that there is statistically significant variation between the concentration of pollutants from gas power plant and the permissible limits of the WHO. This study has reported the quantum of pollutant loads within the vicinity of the gas power plant in the southern part of Nigeria. Evaluation of air pollutant within the vicinity of gas power plant in the southern region of Nigeria show concentration above the permissible limit of the World health Organization (WHO). Data reported in Port Harcourt, Uyo, Calabar, Yenagoa, Benin and Warri show that the area around gas power plants are heavily polluted, but the pollution vary across different intervals from the source. The reports of the WHO show that power plants have the potential to emit 200 tons of fine particulate matter, over 300 tons of nitrogen oxides, and 100 tons of VOCs annually which is consistent with the results of this study. Similar reports by Sillman (2000) show that there is less information and documentation about the quantum of ozone that is generated around coal and gas power plant in air pollution literature given that the emissions from coal power plants and gas power plants are erroneously generalized in many studies. It is reported that the concentration of methane, carbon monoxide, ozone, nitrogen and Sulphur Oxide, and PM2.5 are high and portends severe public health consequences. Gouw *et al*. (2021) contend that the use of natural gas power plant has increased over the last two decades, but estimation of the public health risk is still not sufficiently documented in developed and developing countries. The authors recognized emission of CO2, NOx and SO2 beyond the limits of the WHO. Gouw *et al*. (2021) contend that the switch from coal to natural gas has reduced the emissions from power generation plants, but the emission from gas power plants is also pervasive. Gas power plants in Nigeria are disproportionately located across different states in the southern part of Nigeria due to the availability of natural gas. The pollution reported from the gas power plants in this study could have public health impacts over wider regional areas beyond the vicinity of the plants. This study reported variation in the amount of gas power plants across different cities in the southern part of Nigeria. The reports on the dispersion and distribution of pollutants across different intervals from the gas power plants and across different states is consistent with extant literature. This study revealed that the areas close to the gas power plant between 0 – 200m is more exposed to pollutants from the plant, and there is a gradual but significant reduction in the amount of pollutant concentrated in the atmosphere with movement from the gas power location. However, the results of the study suggest that the concentration of pollutants at 1000m from the gas location is also above the permissible limits of the WHO, which exposes the flora fauna and the residents involved in different occupational activity in the zone between 0 – 1000m to risk. Previous studies have reported that the health impacts of the emissions from gas power plants could extend to hundreds of miles from the power plant stack (Gouw *et al*., 2021). Some of the health risks that have been reported are pre-term births and respiratory diseases. Transition from coal to gas has seen 49% of the in-state electricity generation from natural gas in California in 2016 but burning natural gas emits nitrogen oxides, which can contribute to the formation ozone and particulate matter. Diverse reports maintain in the literature the nexus between air pollution and timing of the day, pollution could be high at any time of the day or night but ozone concentration is highest in the afternoon (Gouw *et al*., 2021). Authors have reported that natural gas is a major source of electricity production in Nigeria. It was reported that 79.5% of the electricity generated in Nigeria is from natural gas while hydroelectricity is second with 20.4%. Concerns have been raised about the impacts of atmospheric emissions associated with gas power plants and effects on climate and air quality by the World health organization. The WHO has reported that urban and rural residents are exposed to diverse public health problems due to prolonged exposure to air pollution. But the documentation of the pollutant concentration across different hours of the day is still weak in the literature. Results of this study suggest that there is significant variation in the concentration of pollutants during the morning, afternoon and evening hours. But the pollutant loads throughout that day exceeds the limits of the WHO. Diverse opinions exist in the literature on the variation of air pollution at different time of the day. Some authors reported that the air is cleaner in the morning close to sources of pollution, while others posits that pollution is less substantial at night-time due to fewer economic activities, particularly in the urban areas where pollution from transportation is immense. However, that data on the generation of electricity from gas power plant suggest that emission levels is continuous, prolonged and relatively constant, and thus the concentration of pollutant in the atmosphere is not entirely due to discontinuation of the activity but a function of time, season and meteorological parameters in the areas.

CONCLUSION AND RECOMMENDATIONS

The generation of electricity from natural gas is a critical component of the Nigerian economy given the low level of electricity generation and the enormous gas deposits in the southern part of the country. The lure to improve the utility of gas deposits to meet the high demand for power is growing, but this is not without attendant environmental and socioeconomic consequences. This study corroborates with previous studies that gas power plants emits appreciable quantum pollutants reported that that all the pollutants which helps to increase the pollutants loads in the atmosphere in the vicinity of some of the gas plants. This study describes and evaluates the pollutant loads within the vicinity of gas power plants in the southern region of Nigeria. The findings of the study are consistent with extant literature, but with significant exception. The quantum of pollutant loads in the atmosphere is higher than the limits set by the World Health Organization. It is reported that the concentration of air pollutant around the vicinity of the gas power plant varies across distance. The communities, flora and fauna close to the gas power plant are more vulnerable given the carbon footprint in the area. The concentration of pollution loads show variation during the day from morning, afternoon and evening. This study found consistency with previous studies on the variation between the pollutants from gas power plants and the permissible limits set by the World Health Organization (WHO). The significant difference between the pollutant loads and the standard of the WHO portend severe public health consequences for resident that are exposed and staff deployed for the operation of the power plants. Therefore, periodic conduct of environmental auditing, regulation of deforestation through legislation, reforestation and afforestation around gas plant including constant air quality monitoring were recommended.

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