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Original Article

Concentrations and Health Implications of PM2.5, PM10, and Gaseous Pollutants in Communities near Ibom Power Company, Ikot Abasi, Nigeria

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Abstract *- Particulate Matter (PM) exposure from ambient air has been linked to a number of ailments, and monitoring is necessary in every industrial areas or centers to identify overexposure early. This study's assessed the concentrations of PM2.5, PM10, and related gaseous pollutants in Ibom Power Company, Ikot Abasi, Nigeria, including carbon monoxide (CO), ozone (O_3), and nitrogen dioxide (NO_2). The concentrations of PM2.5, PM10, NO_2, CO, and O_3 at three chosen towns surrounding Ibom Power Company were measured using an aerosol mass monitor. The hazard quotient (HQ) of the average hourly dose (AHD) and average daily dose (ADD) exposures to the particles was calculated using the obtained values. The findings showed that, with the exception of Ikpetim, where the values (5.26±0.21 and 5.16±0.20 μg/m^3) were below the permitted limits, all of the villages had PM 2.5 and PM 10 levels over the 15μg/m^3 permissible range advised by the WHO. With the exception of Ikpetim, where the NO_2 value was within the limit, all settlements had CO and NO_2 values over the 25μg/m^3 and 7μg/m^3 acceptable levels, respectively. In the meantime, O_3 levels were within allowable bounds (<100μg/m^3) in every community. In several places, the HQ of the ADD was higher than 1, yet the HQ of the AHD of the pollutants was below the threshold of 1. The findings suggest that daily exposure to PM2.5, PM10, NO_2, and CO in certain areas can have detrimental effects on residents' health. It is recommended that government agencies responsible for health and the environment develop policies aimed at reducing pollution, and power plants should not be located near residential areas, but specific areas should be designated for power plant siting.*

Keywords *- Ambient air, Concentrations, Hazard quotient, Particulate matter, Ibom Power Company (IPC).*

1. Introduction

Particulate Matter (PM), otherwise known as Particle Pollution (PP), is described as a mixture of liquid droplets and solid particles suspended in the air[1]. Some of the particles are released from a source, such as unpaved roads, construction sites, fires, fields, and biological material such as spores [1-2]. Some of the particles are also formed from complex chemical reactions in the atmosphere, particularly greenhouse gases such as nitrogen oxides and sulfur dioxide emitted from industries, vehicles, and power plants [1]. In addition, PM can absorb and adsorb a variety of harmful compounds, including volatile organic compounds and polycyclic aromatic hydrocarbons[3]. PMs are of various sizes and shapes, of which those with 2.5–10 micrometers in diameter are considered coarse and referred to as PM10, while those with a diameter of 0.1–2.5 micrometers, defined as fine particles, are designated as PM2.5 [4]. There are also ultrafine particles (UFP), otherwise known as nanoparticles, which are less than 0.1 micrometers in diameter [4]. Only electron microscopes can be used to visualize PM2.5 and is produced mainly from combustive activities such as residential wood burning, industrial processes, power generation, and vehicular emissions [5-6]. Although the compositions of various PMs differ worldwide, they all increase morbidity and mortality [7]. However, PM2.5 is more harmful to health than PM10 [8-9]. This is because while PM10 occupies the upper respiratory system, PM2.5 goes further to reach the alveolar part of the lower respiratory system[10-11]. PM10, on the other hand, crosses the blood–air barrier of the lungs and enters the blood[12]. PM exposure has been linked to lung cancer, chronic obstructive pulmonary disease, cardiovascular disease, autoimmune diseases, neoplastic diseases, and the worsening of a variety of other diseases [13-15]. In the upper atmosphere, PM can modify Earth's radiation and cloud formation, resulting in climate change[16-18]. Urban centers with high populations are the most affected by PM because of multiple sources of combustion, such as vehicles, barbeques, and smoking, among others, as well as industrial activity [19-20]. Thus, it is imperative to constantly monitor the atmospheric levels of PM in every urban center so as to safeguard human health and reduce health burdens. Ikot Abasi in Nigeria is one of the less populous cities in the world, but with high levels of anthropogenic activity, which can potentially result in high levels of PM exposure and health effects. In Nigeria, air pollution has worsened due to increased industrialization, power generation, gas flaring, and vehicular emissions. While studies exist for major cities like Lagos, where PM2.5 exposure caused approximately 11,200 premature deaths and in US it resulted to about $2.1 billion economic burden in 2018, and very little data exists for smaller industrial towns. Critically, there is a paucity of studies on Multi-pollutant concentrations of PM2.5, PM10, CO, NO_2, and O_3 in communities around power plants in Nigeria and Quantitative human health risk assessment for these pollutants in host communities.

Most prior Nigerian PM studies focus on Lagos and fail to link measured concentrations to actual health risk metrics. For Akwa Ibom State, and specifically Ikot Abasi, where the 190 MW Ibom Power Company operates, there is currently no baseline data or health-risk assessment despite ongoing anthropogenic activities. To address this gap, this study was designed as the first health-risk assessment near Ibom Power Company, Ikot Abasi, since its inception. The study aims to determine the ambient concentrations of PM2.5, PM10, CO, NO_2, and O_3 in surrounding communities and to quantify the associated human health risks using Hazard Quotient (HQ) metrics. The findings will provide first-hand data to inform air quality management, reduce PM and gaseous pollutant impacts in the plant and its environs, and establish a baseline for policy and future monitoring in similar power plant communities across Nigeria.

2. Materials and Methods

2.1. Study Area

Ibom power plant is selected due to the numerous complained and health challenges faced by the residents of the area. In addition to the challenges, no health risk assessment is conducted since the establishment of the plant. The development of the Ibom power plant started as a captive power plant for the proposed Akwa Refinery and Petrochemical Company under the administration of the former Governor of Akwa Ibom State, His excellency, Obong Victor Attah. Although the development of the refinery was aborted in 2002, the power plant project continued in phased development. The construction of Phase 1 began in 2005 with the appointment of Group Five as the Engineering, Procurement and Construction (EPC) contractor. Phase 1 has an installed capacity of 191megawatts, which comprises of three (3) units – two (2) GE frames 6B and one GE frame 9E, Gas Turbine Generator (GTG) installed in a simple cycle configuration. Phase 1 commenced operation on December 13, 2009, with the evacuation of 30megawatts to the national grid. In July 2010, former President Goodluck Ebele Jonathan officially switched on Phase 1 of the Ibom power plant. Ibom Power Company (IPC) is located in ikpetim in central ikot abasi local government area of Akwa- Ibom state. It is a 1,000Mw gas fired power project and one of the first independent power plants in Nigeria. IPC was incorporated on the 15th of January, 2001, by akwa Ibom investment and industrial promotion council (AKIIPOC) under the Corporate Affairs Commission (CAC). The company was licensed by the Nigerian Electricity Regulatory Commission (NERC) to generate power and supplied to the National grid for onward distribution.

Fig. 1 Ibom Power Company (IPC)

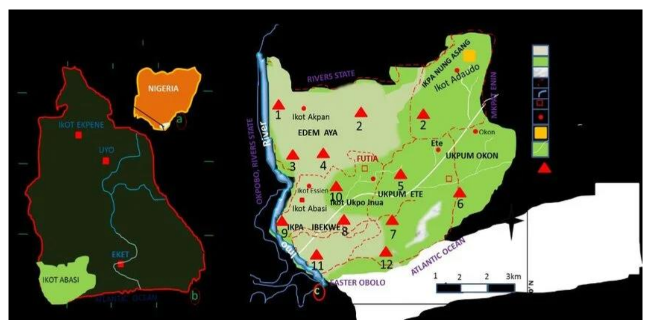

Fig. 2 Map of Ikot Abasi showing Ikpa Ibekwe, Ntuen Ibok and Ikpetim villages

2.2. PM and Gaseous Pollutants Measurement

Three communities near the power plant —Ikpa Ibekwe (IB), Ntuen Ibok (NI), and Ikpetim (IK)—had their PM2.5, PM10, NO2, CO, and O3 concentrations measured using a pre-calibrated Aerosol Mass Monitor from the manufacturer. A 3 km grid distance was maintained between each location from the power plant. At each location for each pollutant, three concentrations were recorded each hour, and these data were used to calculate average hourly concentrations. Readings were taken three times a month in the morning hours for two months, from May to June, 2025, at randomly chosen places or communities near the plant. Additionally, a handheld automatic GPS was used to determine the sampling spots' coordinates. The coordinates are as shown below:

Table 1. Coordinates of the sampled points

Sample point	Code	Latitude	Longitude
Ikpa Ibekwe	IB	4.569°N	7.553°E
Ntuen Ibok	NI	4.568°N	7.567°E
Ikpetim	IK	4.808°N	7.742°E

Detection Limits**:** PM2.5: 0.1 µg/m³ - 1000 µg/m³ PM10: 0.1 µg/m³ - 1000 µg/m³

Calibration Procedure: The EPAM 5000 was calibrated using a reference method, such as gravimetric analysis or comparison with a certified standard. Calibration is typically performed at multiple concentration points to ensure accuracy. The instrument also have an internal zero and span check for quality control.

2.3. Health Risk Assessment

Equations 1, 2, and 3 were used to determine the PM's health hazards based on average hourly dose (AHD), average daily dose (ADD), and hazard quotient (HQ) [21].

$$\text{AHD} = \frac{Cn \times IR}{BW} \quad [1]$$

$$ADD = \frac{Cn \times ED \times IR}{ABW \times AT} \quad [2]$$

$$HQ = \frac{AHD \;\; ADD}{RL} \quad [3]$$

where Cn is the particulate matter concentration (µg/m3); IR is the inhalation rate in m3/hour per person per day (day-1), which is 1.2; EF is the frequency of exposure (365 days/year); ED is the duration of exposure (55 years, the average life span of a Nigerian); and ABW is the average body weight (65 kg = 6.5x107 µg); RL is for reference exposure level (10µg/m^3), [22] and AT is the average exposure duration for non-carcinogenic health risk (365 days/year × ED). The target hazard quotient (HQ) is set at 1, and the target cancer risk (CR) is set at 1×10^{-6}. This means the exposure level is equal to the reference dose (RfD) or reference concentration(RfC). HQ>1 indicates potential health risk; HQ<1 indicates low risk. Cancer risk (CR) of 1×10^{-6} represents a cancer risk of 1 in 1,000,000(one in a million). It's considered a benchmark for the acceptable risk level for carcinogenic substances.

2.4. Analysis of Data

The concentrations of PM2.5, PM10, and gaseous pollutants in the atmosphere (NO_2, CO, and O_3) were expressed as mean ± standard deviation (SD). The calculations for the average hourly dose (AHD), average daily dose (ADD), and hazard quotient (HQ) were performed using the software.

3. Results

3.1. Particulate matter and gaseous pollutants Concentrations

Table 1 shows the levels of PM2.5, PM 10, NO_2, CO, and O_3 in the ambient air of Ntuen Ibok (NI), Ikpetim (IK) and Ikpa Ibekwe (IB), all in Ikot Abasi Local Government Area, Nigeria.

The levels of PM 2.5 (16.20, 5.26, 31.23 µg/m^3), PM 10 (15.3, 5.16, 30.20 µg/m^3), NO_2 (27.02, 6.92, 26.51 µg/m^3), CO (34.20, 18.10, 58.03 µg/m^3) and O_3 (28.20, 22.20, 20.43 µg/m^3) in all the villages surrounding the power plant, the levels exceeded the permissible limits set by the World Health Organization [23], with the exception of IK, where the measurements for PM2.5, PM10, NO_2, and O_3 were within acceptable limits.

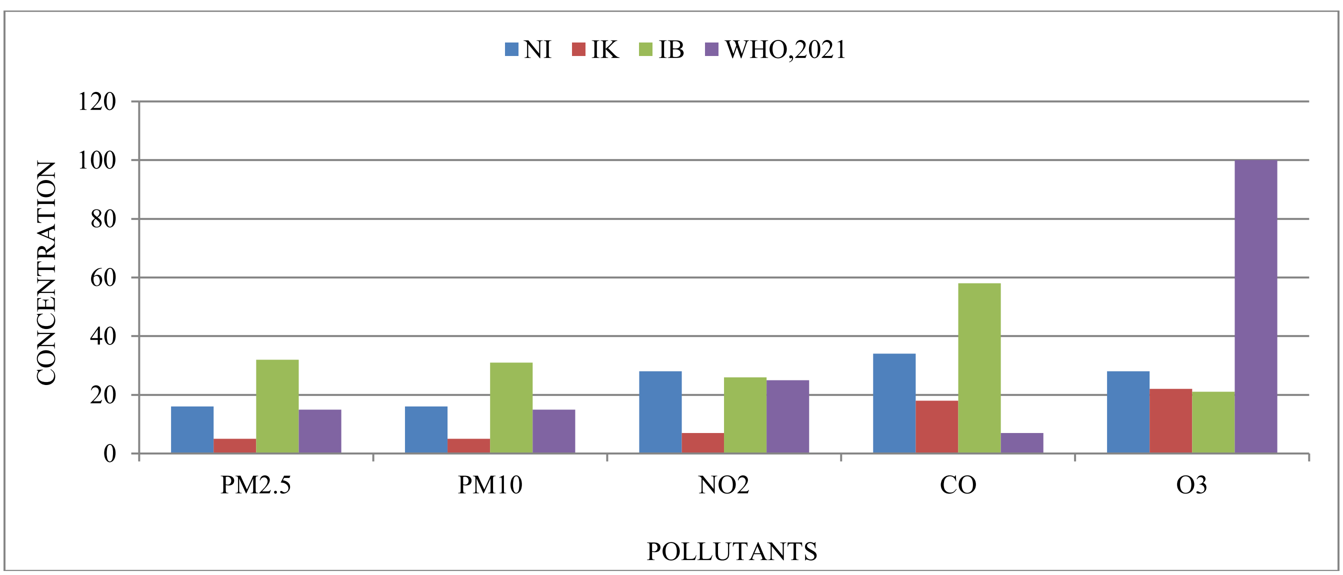

Fig. 3 Particulate matter(PM2.5 and PM10) and Gaseous pollution levels in the surrounding air at Ibom power company in Ikot Abasi LGA in µg/m³

Table 1. PM2.5 and PM10 and gaseous pollution levels in the surrounding air at Ibom Power Company in Ikot Abasi LGA, Nigeria

Location	PM2.5	PM10	NO_2	CO	O_3
NI	16.20±0.63	15.30±0.50	27.02±0.11	34.20±0.91	28.20±0.80
IK	5.26±0.21	5.16±0.20	6.92±0.06	18.10±0.36	22.20±0.66
IB	31.23±0.63	30.20±0.70	26.51±0.66	58.03±2.34	20.43±0.13
Limits [14]	15μg/m^3	15 μg/m^3	25μg/m^3	7μg/m^3	100μg/m^3
Values were expressed as Mean ± SD and μg/m^3, WHO=World Health Organization, NI=Ntuen Ibok, IK=Ikpetim, IB =Ikpa Ibekwe					

3.2. Evaluation of Air Pollution's Health Risks

The average daily dose (ADD) and average hourly dose (AHD) of the pollutants (PM2.5, PM10, NO_2, CO, and O_3) are displayed in Table 2. The hourly doses were lower than the daily dose levels. The greatest PM2.5 AHD and ADD values were observed at IB at 0.59 and 13.99 μg/m^3, respectively, whereas the lowest values were reported at IK at 0.11 and 2.35 μg/m3. The highest concentrations of PM10 AHD and ADD were found at IB (0.53 and 13.80 μg/m^3, respectively), while the lowest concentrations were found at IK (0.10 and 2.20 μg/m3). IK has the lowest quantities of AHD and ADD of NO2 (0.12 and 2.72 μg/m^3), whereas IB has the greatest concentrations (0.36 and 8.90 μg/m^3). While the AHD and ADD of CO showed the lowest concentrations at IK (0.34 and 8.10 μg/m^3) and the highest values at IB (1.13 and 27.33 μg/m^3), the O_3 showed the lowest concentrations at IB (0.22 and 5.17 μg/m^3) and the highest values at NI (0.42 and 9.84 μg/m^3), respectively.

The hazard quotient for the average hourly dose (HQAHD) and the hazard quotient for the average daily dose (HQADD) of the pollutants is shown in Table 3. The HQAHD for all pollutants was below 1 at each of the locations studied. In contrast, the HQADD for PM2.5, PM10, NO_2, CO, and O_3 exceeded 1 at all locations.

Table 2. The average hourly dose (AHD) and average daily dose (ADD) of particulate matter (PM2.5 and PM10), nitrogen dioxide (NO_2), carbon monoxide (CO), and ozone (O_3) in the ambient air of specific villages surrounding the Ibom power company in Ikot Abasi LGA

	PM2.5		PM10		NO_2		CO		O_3	
Location	AHD	ADD	AHD	ADD	AHD	ADD	AHD	ADD	AHD	ADD
NI	0.32	7.45	0.30	7.20	0.32	7.52	0.49	10.21	0.42	9.84
IK	0.11	2.35	0.10	2.20	0.12	2.72	0.34	8.10	0.41	9.76
IB	0.59	13.99	0.53	13.80	0.36	8.90	1.13	27.33	0.22	5.17

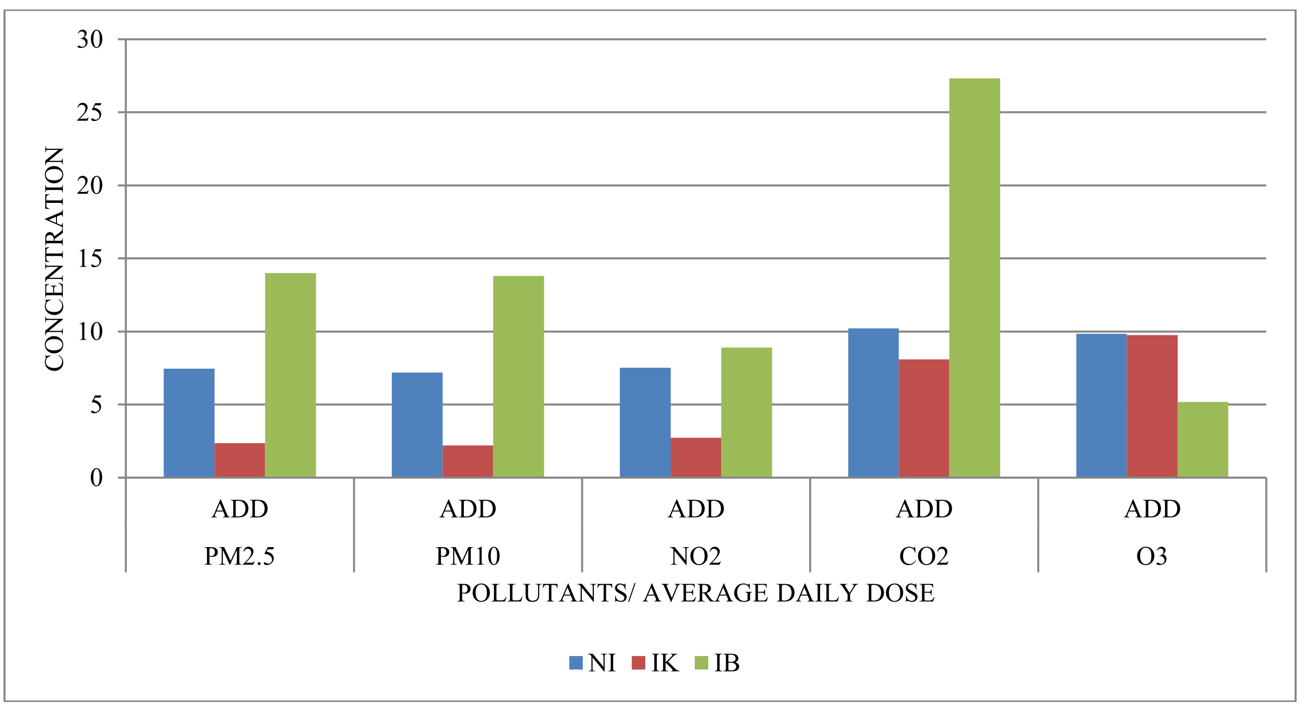

Fig. 4 The Average hourly dose and average daily dose of particulate matter and gaseous pollutants concentrations of ambient air around Ibom power company in Ikot Abasi LGA

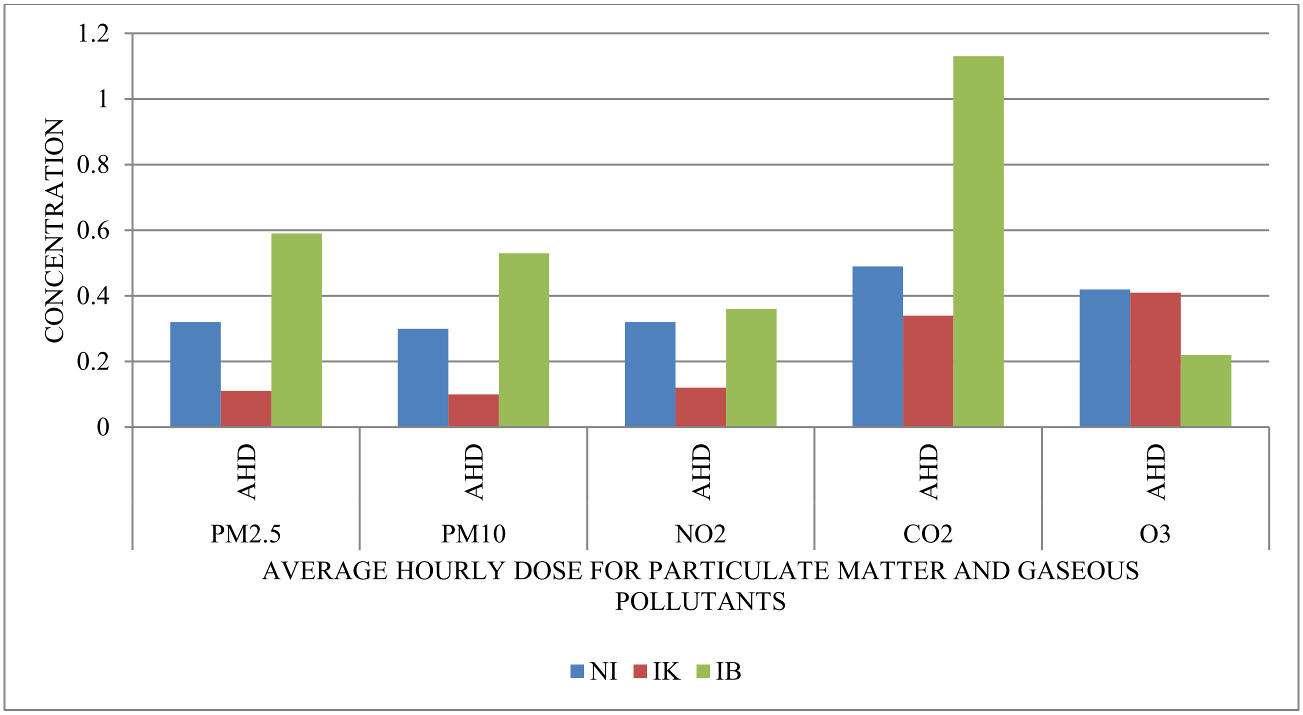

Fig. 5 Average hourly dose for particulate matter and gaseous pollutants for ambient air around Ibom power company in Ikot Abasi LGA

Table 3. The Hazard Quotient (HQ) of the average daily dosage (ADD) of particulate matter (PM2.5 and PM10), nitrogen dioxide (NO_2), carbon monoxide (CO), and ozone (O_3) in the ambient air of specific villages within the Ibom Power Company in Ikot Abasi LGA.

	PM2.5		PM10		NO_2		CO		O_3	
Location	HQ_{AHD}	HQ_{ADD}	HQ_{AHD}	HQ_{ADD}	HQ_{AHD}	HQ_{ADD}	HQ_{AHD}	HQ_{ADD}	HQ_{AHD}	HQ_{ADD}
NI	0.12	0.76	0.11	0.78	0.15	0.76	0.17	1.00	0.32	1.00
IK	0.13	0.36	0.21	0.35	0.16	0.37	0.41	0.77	0.14	1.00
IB	0.14	1.32	0.14	1.20	0.22	0.78	0.37	2.76	0.31	0.57

4. Discussion

The purpose of the current study was to assess the levels and health risks of gaseous pollutants and particulate matter (PM2.5 and PM10) in the ambient air at Ibom Power Company in Nigeria. In order to accomplish the aforementioned goals, ambient air quality was recorded and documented in three villages near Ibom Power Company: Ntuen Ibok (NI), Ikpetim (IK), and Ikpa Ibekwe (IB). PM2.5, PM10, NO_2, and CO were all above the allowable limits, with the exception of PM2.5, PM10, and NO_2 at IK, which were below the allowable limit. Concentration of Ozone(O_3) was within the World Health Organization's allowable limits in every location. This finding implies that the power plant is contaminating the air above the city. The industrial regions of Ntuen Ibok, Ikpetim, and Ikpa Ibekwe—which include a power plant and an aluminum smelting company—are densely populated and have a lot of intense human activity, all of which could have significantly increased the city's air pollution. The study supports the findings of Perrino *et al.* [24], who showed elevated PM in three Southern Italian industrial districts. According to Karagulian *et al*. [25], traffic is responsible for 25% of global urban ambient air pollution from PM2.5 and PM10, with industrial activities accounting for 15%, household fuel burning for 20%, unexplained human sources for 22%, and natural dust and salt for 18%. Locals may be at risk for health problems due to PM and associated compounds in the ambient air surrounding the Ibom power station, given the levels identified in the current study. Both short-term and long-term exposure to PM2.5 and PM10 can lead to respiratory and cardiovascular problems [26]. Furthermore, studies show that exposure to PM2.5 and PM10 may increase the risk of type 2 diabetes mellitus due to endothelial dysfunction, altered immune responses in visceral adipose tissues, and endoplasmic reticulum stress, which can impact glucose metabolism and insulin transduction and sensitivity [27]. Long-term NO_2 exposure lowers lung function, increases the risk of respiratory and cardiovascular disorders, exacerbates bronchitis symptoms in asthmatic patients, and raises mortality rates in the elderly [28–30]. Additionally, NO_2 pollution might change immunological function, making people more susceptible to illnesses [31]. Reduced hemoglobin oxygen transport may result from CO exposure [32]. An inflammatory reaction brought on by chronic CO poisoning may end in brain impairment and unconsciousness [33]. The current study's results are in line with those of Odekanle *et al*. [34], who found PM2.5, PM10, SO_2, and NO_2 levels in ambient air that were prohibited. The findings are similarly consistent with those of Owoade *et al*. [35] and Chiedu *et a*l. [36], who reported unacceptable levels of PM2.5, PM10, and evidence of certain constituents in Lagos' industrialized urban districts. Similarly, in Yaba Local Government Area, Lagos State, Obanya *et al*. [37] found PM 2.5 and PM10 levels that were prohibited. Every hour and every day, the health hazards related to human exposure to PM and gaseous contaminants in the air were assessed. The Hazard Quotient (HQ) of the Average Hourly Dose (AHD) for the PM was less than one, but the Average Daily Dosage (ADD) was greater than one in most of the sites. This implies that residents' health may be negatively impacted by daily exposure to PM2.5, PM10, NO2, CO, and O3. These results suggest that one of the main causes of death at Ibom Power Company is exposure to ambient air pollution. A study carried out in Lagos by Croitoru *et al*. [38] estimated that PM2.5 and PM10 were responsible for over 11,200 premature deaths in 2018. The results of this investigation are consistent with those of Odekanle *et al.* [39], who discovered excessive amounts of PM and associated elements in the ambient air near an abattoir in Ile-Ife, Osun State, Nigeria. Seiyaboh *et al*. [40] discovered hazardous PM levels close to a football field in Yenagoa, Bayelsa State, Nigeria, due to vehicle emissions.

5. Conclusion

The findings showed that while PM2.5 and PM10 were within allowable limits in Ikpetim (IK), they were beyond allowable limits in Ntuen Ibok (NI) and Ikpa Ibekwe (IB). With the exception of Ikpetim (IK), NO_2 levels were higher than allowed in every location. While O_3 levels were within permissible bounds in every hamlet, CO levels were higher than allowed levels in every village. While the Hazard Quotient (HQ) of the Average Hourly Dose (AHD) was less than one, the Average Daily Dosage (ADD) of the PM was greater than one. Overall, the findings indicate that daily exposure to PM2.5, PM10, NO_2, and CO poses a risk to one's health. Activities that release pollutants should be managed in order to lower PM and related pollution. Residential neighborhoods near power plants should be avoided in particular, and the plant's appliances should be powered more frequently by electricity and biogas than by generators. The government should create regulations to reduce pollution, such as banning the use of smoke generators in power plants and designating particular regions for the placement of power plants far from residential areas.

Authors' Contributions

Ioryue I. Silas, Abah E. Bridget and Macdougal N. Saddie: writing-original draft; formal analysis; Augustine A.U, Ekpenyong O. Ukofia and Akpanuko M. Emmanuel did writing-review and editing. Idongesit S.Ambrose: conceptualization; writing, review, and editing. All the authors have read and approved the manuscript for submission.

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Data Availability Statement

Supporting data are available and embedded in the researched article.

Conflict of Interest

The authors declare no conflict of interest.

References

[1] USEPA United States Environmental Protection Agency, Particulate Matter (PM) Pollution, 2022. [Online]. Available: https://www.epa.gov/pm-pollution/particulate-matter-pm-basics

[2] Alexander Iheanyichukwu Opara et al., "Particulate Matter Exposure and Non-Cancerous Inhalation Health Risk Assessment of Major Dumpsites of Owerri Metropolis, Nigeria," *Environmental Analysis, Health and Toxicology*, vol. 36, no. 4, pp. 1-12, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[3] Jian Zhen Yu et al., "Nonpolar Organic Compounds in Fine Particles: Quantification by Thermal Desorption-GC/MS and Evidence for their Significant Oxidation in Ambient Aerosols in Hong Kong," *Analytical and Bioanalytical Chemistry*, vol. 401, no. 10, pp. 3125-3139, 2011. [CrossRef] [Google Scholar] [Publisher Link]

[4] Walter J. Crinnion, and Joseph Pizzorno, "Particulate Matter is a Surprisingly Common Contributor to Disease," *Integrative Medicine: A Clinician's Journal*, vol. 16, no. 4, pp. 8-12, 2017. [Google Scholar]

[5] Giulia Cesaroni et al., "Long Term Exposure to Ambient Air Pollution and Incidence of Acute Coronary Events: Prospective Cohort Study and Meta-Analysis in 11 European Cohorts from the ESCAPE Project," *BMJ Clinical Research*, vol. 348, pp. 1-16, 2014. [CrossRef] [Google Scholar] [Publisher Link]

[6] Evangelia Samoli et al., "Acute Effects of Ambient Particulate Matter on Mortality in Europe and North America: Results from the APHENA Study," *Environmental Health Perspective*, vol. 116, no. 11, pp. 1480-1486, 2008. [CrossRef] [Google Scholar] [Publisher Link]

[7] Kate Adams et al., "Particulate Matter Components, Sources, and Health: Systematic Approaches to Testing Effects," *Journal of the Air and Waste Management Association*, vol. 65, no. 5, pp. 544-558, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[8] Jonathan O. Anderson, Josef G. Thundiyil, and Andrew Stolbach, "Clearing the Air: A Review of the Effects of Particulate Matter Air Pollution on Human Health," *Journal of Medical Toxicology*, vol. 8, no. 2, pp. 166-175, 2012. [CrossRef] [Google Scholar] [Publisher Link]

[9] Qing Chen et al., "Particulate Matter and Ozone Might Trigger Deaths from Chronic Ischemic Heart Disease," *Ecotoxicology and Environmental Safety*, vol. 242, pp. 1-8, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[10] Ruiming Liang et al., "Associations of Long-Term Exposure to Fine Particulate Matter and its Constituents with Cardiovascular Mortality: A Prospective Cohort Study in China," *Environment International*, vol. 162, pp. 1-9, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[11] Wei Liu et al., "Particulate Matter Pollution and Asthma Mortality in China: A Nationwide Time-Stratified Case-Crossover Study from 2015 to 2020," *Chemosphere*, vol. 308, pp. 1-9, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[12] Yixing Du et al., "Air Particulate Matter and Cardiovascular Disease: The Epidemiological, Biomedical and Clinical Evidence," *Journal of Thoracic Disease*, vol. 8, no. 1, pp. E8-E19, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[13] Prakash Thangavel, Duckshin Park, and Young-Chul Lee, "Recent Insights into Particulate Matter ($PM_{2.5}$)-Mediated Toxicity in Humans: An Overview," *International Journal of Environmental Research and Public Health*, vol. 19, no. 12, pp. 1-22, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[14] Hu Chen et al., "Analysis of Air Quality Change Characteristics and Correlation with Meteorological Factors in Yangtze River Delta City Cluster," *Academic Journal of Environment and Earth Science*, vol. 5, no. 9, pp. 51-61, 2023. [CrossRef] [Publisher Link]

[15] Anoop S.V. Shah et al., "Global Association of Air Pollution and Heart Failure: A Systematic Review and Meta-Analysis," *The Lancet*, vol. 382, no. 9897, pp. 1039-1048, 2013. [CrossRef] [Google Scholar] [Publisher Link]

[16] Jae-Eun Lee, Hyun Joung Lim, and Young-Youl Kim, "Publication Trends in Research on Particulate Matter and Health Impact over a 10-Year Period: 2009-2018," *Environmental Analysis, Health and Toxicology*, vol. 36, no. 1, pp. 1-13, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[17] Jahan Zeb Khan et al., "Size Distribution of Ambient Particulate Matter and its Constituent Chemical Species Involving Saccharides during Early Summer in a Chinese Megacity," *Frontiers in Environmental Sciences*, vol. 9, pp. 1-15, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[18] Arideep Mukherjee, and Madhoolika Agrawal, "World Air Particulate Matter: Sources, Distribution and Health Effects," *Environmental Chemistry Letters*, vol. 15, no. 2, pp. 283-309, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[19] R.A. Alani et al., "The Level $PM_{2.5}$ and the Elemental Compositions of Some Potential Receptor Locations in Lagos, Nigeria," *Air Quality Atmosphere and Health*, vol. 12, no. 10, pp. 1251-1258, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[20] Robert B. Hamanaka, and Gökhan M. Mutlu, "Particulate Matter Air Pollution: Effects on the Cardiovascular System," *Frontiers in Endocrinology*, vol. 9, pp. 1-15, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[21] Oyewale Mayowa Morakinyo et al., "Health Risk of Inhalation Exposure to Sub-10 µm Particulate Matter and Gaseous Pollutants in an Urban-Industrial Area in South Africa: An Ecological Study," *BMJ Open*, vol. 7, no. 3, pp. 1-9, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[22] Sakwe Adianimovie, and Gbeinzi Ebinimi, "Investigation of Particulate Matter (PM10 & PM2.5) and Gaseous Pollutants (CO_2 & CO) in Houses Using Kerosene Cooking Stoves & Wood Fire in Attisa 3, Bayelsa State, Nigeria, NIPES," *Journal of Science and Technology Research*, vol. 5, no. 2, pp. 206-219, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[23] World Health Organization, *Global Air Quality Guidelines. Particulate Matter (PM2.5 and PM10), Ozone, Nitrogen Dioxide, Sulfur Dioxide, and Carbon Monoxide*, Geneva: World Health Organization, 2021. [Google Scholar]

[24] Cinzia Perrino et al., "Air Quality Characterization at Three Industrial Areas in Southern Italy," *Frontiers in Environmental Science*, vol. 7, pp. 1-18, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[25] Federico Karagulian et al., "Contributions to Cities' Ambient Particulate Matter (PM): A Systematic Review of Local Source Contributions at Global Level," *Atmospheric Environment*, vol. 120, pp. 475-483, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[26] J. Lambrechtsen et al., "The Relation between Coronary Artery Calcification in Asymptomatic Subjects and both Traditional Risk Factors and Living in the City Centre: A DanRisk Sub Study," *Journal of Internal Medicine*, vol. 271, no. 5, pp. 444-450, 2012. [CrossRef] [Google Scholar] [Publisher Link]

[27] Dian He et al., "Association between Particulate Matter 2.5 and Diabetes Mellitus: A Meta-Analysis of Cohort Studies," *Journal of Diabetes Investigation*, vol. 8, no. 5, pp. 687-696, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[28] Małgorzata Kowalska et al., "Effect of NO_x and NO_2 Concentration Increase in Ambient Air to Daily Bronchitis and Asthma Exacerbation, Silesian Voivodeship in Poland," *International Journal of Environmental Research and Public Health*, vol. 17, no. 3, pp. 1-9, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[29] Xia Meng et al., "Short Term Associations of Ambient Nitrogen Dioxide with Daily Total, Cardiovascular, and Respiratory Mortality: Multilocation Analysis in 398 Cities," *BMJ Clinical Research*, vol. 372, pp. 1-9, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[30] Yaoyao Qian et al., "Long-Term Exposure to Low-Level NO_2 and Mortality among the Elderly Population in the Southeastern United States," *Environmental Health Perspective*, vol. 129, no. 12, pp. 1-9, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[31] Agostino Di Ciaula et al., "Nitrogen Dioxide Pollution Increases Vulnerability to COVID-19 through Altered Immune Function," *Environmental Science and Pollution Research*, vol. 29, no. 29, pp. 44404-44412, pp. 1-9, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[32] Ivan Blumenthal, "Carbon Monoxide Poisoning," *Journal of the Royal Society of Medicine*, vol. 94, no. 6, pp. 270-272, 2001. [CrossRef] [Google Scholar] [Publisher Link]

[33] Claire L. Townsend, and Robert L. Maynard, "Effects on Health of Prolonged Exposure to Low Concentrations of Carbon Monoxide," *Occupational and Environmental Medicine*, vol. 59, pp. 708-711, 2002. [CrossRef] [Google Scholar] [Publisher Link]

[34] E.L. Odekanle et al., "COVID-19 Induced Restriction in Developing Countries and its Impacts on Pollution Load: Case Study of Lagos Mega City," *Heliyon*, vol. 8, no. 8, pp. 1-9, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[35] O.K. Owoade et al., "EDXRF Elemental Assay of Airborne Particulates: A Case Study of an Iron and Steel Smelting Industry, Lagos, Nigeria," *Scientific Research and Essay*, vol. 4, no. 11, pp. 1342-1347, 2009. [Google Scholar] [Publisher Link]

[36] Chiedu I Emmanue et al., "Source Identification and Heavy Metal Analysis of Fine Particulate Matter ($PM_{2.5}$) in an Industrialized Urban Area of Lagos State, Nigeria," *Journal of Environmental Analytical Chemistry*, vol. 6, no. 3, pp. 1-5, 2019. [Publisher Link]

[37] Henry E. Obanya et al., "Air Pollution Monitoring Around Residential and Transportation Sector Locations in Lagos Mainland," *Journal of Health and Pollution*, vol. 8, no. 19, pp. 1-10, 2018. [Google Scholar]

[38] Lelia Croitoru, Jiyoun Christina Chang, and Joseph Akpokodje, "The Health Cost of Ambient Air Pollution in Lagos," *Journal of Environmental Protection*, vol. 11, no. 9, pp. 753-765, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[39] Ebenezer Leke Odekanle et al., "Air Emissions and Health Risk Assessment Around Abattoir Facility," *Heliyon*, vol. 6, no. 7, pp. 1-8, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[40] Enetimi I. Seiyaboh, Tariwari C.N Angaye, and Odangowei I. Ogidi, "Environmental and Health Risk Assessment of Particulate Matter Associated with Dusty Football Field," *Journal of Experimental and Clinical Toxicology*, vol. 1, no. 2, pp. 1-6, 2019. [CrossRef] [Google Scholar] [Publisher Link]