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Air Pollution Assessment from Plastic Waste Combustion in Residential Areas near Dumpsites in Port Harcourt

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ABSTRACT

The The combustion of plastic waste near urban dumping and incineration sites in Port Harcourt, Rivers State, Nigeria, poses significant environmental and public health challenges. This study evaluated air quality and health risks at five major dumpsites Eneka, Igbo-Etche, Bori, Oyigbo, and Rukpokwu during the dry season. Key air pollutants, including particulate matter (PM2.5 and PM10), carbon monoxide (CO), volatile organic compounds (VOCs), nitrogen oxides (NOx), and dioxins, were measured. Results showed PM2.5 concentrations ranging from 85 µg/m³ to 170 µg/m³, far exceeding the WHO's 24-hour guideline of 15 µg/m³. Similarly, NOx levels peaked at 240 ppb, surpassing the 100 ppb limit. Contamination Factor (CF) analysis revealed severe contamination levels for PM2.5 (CF: 5.7–11.3) and NOx (CF: 2.4), while the Degree of Contamination (DC) indicated an alarming cumulative pollution level across all sites (DC: 45–78). Health risk assessments showed a 35% higher prevalence of respiratory and cardiovascular diseases among residents within 2 km of the sites, with children and the elderly being the most affected. The findings underscore the urgent need for improved waste management, stricter environmental policies, and community education to mitigate the adverse effects of plastic waste combustion. By presenting critical data on contamination and associated health risks, this research aims to guide policymakers in developing sustainable strategies to protect vulnerable populations and improve urban air quality in Port Harcourt, Nigeria.

Keywords: Air pollution, plastic waste, dump site, residential areas

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INTRODUCTION

Air pollution remains a critical global environmental and public health issue, particularly in rapidly urbanizing cities of low- and middle-income countries where solid waste management systems are often inadequate (World Health Organization [WHO], 2021; United Nations Environment Programme [UNEP], 2019). Open burning of municipal solid waste is a widespread practice used to reduce waste volume in the absence of engineered landfills or effective recycling systems (World Bank, 2018). Among the various components of municipal waste, plastics constitute a significant and increasingly dominant fraction due to their extensive use in packaging, household goods, and consumer products (Organization for Economic Co-operation and Development [OECD], 2022). The uncontrolled combustion of plastic waste releases a complex mixture of hazardous air pollutants, including fine particulate matter ($PM_{2.5}$ and PM_{10}), carbon monoxide (CO), nitrogen oxides (NO_x), sulfur dioxide (SO_2), volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), and highly toxic persistent organic pollutants such as dioxins and furans (United States Environmental Protection Agency [USEPA], 2018; World

Health Organization, 2010). These emissions pose serious risks to human health, ecosystems, and climate stability (WHO, 2021).

In sub-Saharan Africa, rapid population growth and urban expansion have intensified pressure on existing waste management infrastructure (UNEP, 2019). Nigeria, the most populous country in Africa, generates substantial quantities of plastic waste annually, much of which is disposed of through open dumping and burning (World Bank, 2018; OECD, 2022). In Port Harcourt, a major industrial and commercial hub in the Niger Delta region, open combustion of plastic waste at dumpsites and within nearby residential neighborhoods has become a routine waste disposal method. The city has previously experienced episodes of severe air pollution, notably the prolonged soot crisis that drew national and international attention (National Environmental Standards and Regulations Enforcement Agency [NESREA], 2019). Although multiple sources contribute to degraded air quality in Port Harcourt including industrial emissions, gas flaring, vehicular exhaust, and artisanal refining the contribution of plastic waste combustion in residential areas adjacent to dumpsites remains insufficiently quantified.

The combustion of plastics under uncontrolled, low-temperature conditions typically results in incomplete oxidation and the formation of toxic by-products. Polyvinyl chloride (PVC), for example, releases hydrogen chloride and dioxins when burned, while polyethylene and polypropylene generate particulate-bound PAHs and other organic pollutants (USEPA, 2018; UNEP, 2019). Residents living in close proximity to dumpsites are therefore exposed to elevated levels of airborne contaminants, often without adequate protective measures. Chronic exposure to emissions from plastic burning has been associated with increased incidence of respiratory disorders, cardiovascular diseases, impaired lung function, adverse pregnancy outcomes, and elevated cancer risk (WHO, 2010; WHO, 2021). Children, the elderly, and individuals with pre-existing health conditions are particularly vulnerable to the adverse effects of air pollution. Despite the recognized hazards of open plastic waste burning, there is a paucity of localized, peer-reviewed data quantifying pollutant concentrations and characterizing exposure levels in residential areas near dumpsites in Port Harcourt. Many previous studies in Nigeria have focused on industrial pollution or general urban air quality trends, with limited emphasis on micro-environmental assessments around waste disposal sites. The absence of site-specific data constrains effective environmental regulation, health risk assessment, and evidence-based policymaking (NESREA, 2019). Therefore, a systematic air pollution assessment focused on plastic waste combustion in residential communities surrounding dumpsites in Port Harcourt is both timely and necessary. Such an assessment will enable the quantification of key gaseous and particulate pollutants, evaluation of spatial variation in contaminant levels, and comparison with national and international air quality standards (WHO, 2021). Furthermore, identifying the contribution of plastic combustion to overall ambient pollution will support the development of targeted mitigation strategies, improved waste management policies, and public health interventions. This study aims to assess the extent and characteristics of air pollution arising from plastic waste combustion in residential areas near dumpsites in Port Harcourt. By generating empirical data on pollutant concentrations and potential exposure risks, the research seeks to contribute to the growing body of literature on waste-related air pollution in developing urban settings and to provide scientific evidence necessary for environmental protection and sustainable urban management.

METHODOLOGY

Study Area

The study focused on five urban dumpsites in Port Harcourt, Rivers State: Eneka, Igbo-Etche, Bori, Oyigbo, and Rukpokwu. These dumpsites were chosen due to their high levels of plastic waste incineration and their proximity to densely populated residential areas. Initially commissioned when urbanization had not yet spread to these locations, these areas were more rural with lower population densities and minimal industrial activity. However, over the past few decades, rapid urbanization in Port Harcourt has transformed these once sparsely populated regions into densely developed urban neighborhoods. This urban sprawl has led to increased commercial, residential, and industrial activities, heightening the demand for effective waste management systems. Unfortunately, the rapid development has outpaced infrastructure growth, leading to improper waste disposal and the open burning of plastic waste. As a result, the residents of these areas are increasingly exposed to the harmful effects of plastic waste combustion, including the release of toxic air pollutants such as particulate matter, carbon monoxide, sulfur dioxide, and volatile organic compounds. The selection of these dumpsites is critical because their transformation from rural to urban spaces highlights the intersection of urbanization and environmental challenges. The ongoing waste management issues in these newly developed areas make them ideal locations for assessing the air quality impacts of plastic incineration and understanding the environmental and public health implications for residents living nearby.

Estimation of Ambient Air Quality

The study assessed the air quality in residential areas surrounding the selected dumpsites in Port Harcourt,

Rivers State. This involved using portable instruments and appropriate sampling intervals to understand the impact of plastic waste combustion on air quality.

Portable Air Quality Monitors

Portable air quality monitors- Aeroqual Series 200- was used to measure concentrations of various gaseous pollutants (e.g., VOCs, CO, and NO_2). These monitors were deployed in residential areas adjacent to the dumpsites to capture the impact of incineration on local air quality.

Multi-Parameter Anemometer

Wind speed and direction were measured using a multi-parameter digital anemometer, Model No. 45170. This instrument was positioned away from obstructions to ensure accurate readings. Wind measurements will help determine the dispersion patterns of pollutants from the dumpsites into nearby residential areas.

TESTO Gas Analyzer for Inorganic Pollutants

The TESTO 350-XL gas analyzer was employed to assess inorganic pollutants such as SO_2, NOx, and CO. The analyzer's ability to store data for up to 48 hours will facilitate the tracking of pollutant levels over the study period, ensuring that emissions from incineration are adequately captured.

Particulate Matter Analyzer

To measure suspended particulate matter (PM_{10} and $PM_{2.5}$), a mini-volume portable air sampler was utilized. Air was drawn through a pre-weighed filter over a 4-hour sampling period, allowing for the collection of data on particulate concentrations associated with incineration events.

Sample Collection Interval

The samples were collected when incineration activities are prevalent, it was conducted less frequently but strategically. Sampling occurred at two designated intervals each day: one in the morning (e.g., 8:00 AM to 12:00 PM) and one in the evening (e.g., 4:00 PM to 8:00 PM). This approach allowed for effective monitoring of air quality during peak activity periods while accounting for the distances between the residential areas and the dumpsites.

Determination of Contamination Factor (CF)

The contamination factor (CF) for each air quality parameter at each location was calculated by comparing the observed concentration to the background concentration. The formula used for calculating CF is as follows:

$$CF = \frac{\text{Observed Concentration}}{\text{Background Concentration}}$$

Where:
Observed Concentration is the concentration of the specific air quality parameter measured at a given location.
Background Concentration is the baseline value for that specific air quality parameter, which represents the expected concentration in a relatively unpolluted area. The background concentrations used in this study are:
$PM_{2.5}$: 12 µg/m³
PM_{10}: 20 µg/m³
SO_2: 0.003 ppm
NO_2: 0.02 ppm
CO: 0.5 ppm
VOCs: 0.1 ppm

The CF values provide a quantitative measure of how much the air quality parameters exceed their expected baseline levels. A CF greater than 1 indicates elevated levels of the specific pollutant in the air compared to the background concentration.

Determination of Degree of Contamination (DC)

The degree of contamination (DC) for each location was determined by summing the contamination factors (CF) of all air quality parameters ($PM_{2.5}$, PM_{10}, SO_2, NO_2, CO, and VOCs) for both morning and evening periods. The formula used to calculate DC is:
$DC = \sum CF$ of all parameters

Where:
DC (Morning) is the total contamination factor calculated for the morning observations (6:00 AM to 9:00 AM).
DC (Evening) is the total contamination factor calculated for the evening observations (6:00 PM to 9:00 PM).

The degree of contamination is categorized as follows:
Low Contamination: $DC \leq 15$
Moderate Contamination: $15 < DC \leq 25$
High Contamination: $DC > 25$

These ranges are based on a classification system adapted from previous studies on air quality and environmental contamination (Zhang et al., 2019; Kumar & Patel, 2020). The DC value provides an overall indication of the air pollution level at each location, considering all monitored air quality parameters. Higher DC values signify higher levels of pollution and a greater degree of environmental contamination. This allows for a

comprehensive understanding of the pollution intensity at each site during both morning and evening times.

RESULTS AND DISCUSSION

The results of the air quality assessment across Eneka, Igbo-Etche, Bori, Oyigbo, and Rukpokwu reveal clear spatial and temporal variations in pollutant concentrations. As shown in (Table 1 and Table 2), particulate matter (PM2.5 and PM10) levels were consistently higher in the evening compared to the morning across all locations. At Eneka, PM2.5 increased from 128.5 ± 18.6 µg/m³ in the morning to 148.7 ± 21.8 µg/m³ in the evening, while PM10 rose from 202.4 ± 29.5 µg/m³ to 232.8 ± 33.6 µg/m³. These values far exceed the WHO guideline limits of 10 µg/m³ (PM2.5) and 20 µg/m³ (PM10) (WHO, 2021), underscoring severe air quality concerns. The evening rise is likely attributable to increased vehicular traffic, industrial operations, and reduced atmospheric dispersion due to lower wind speeds and temperature inversions, consistent with findings by Balogun et al. (2017). Bori consistently recorded the lowest particulate matter levels (morning PM2.5: 112.4 ± 16.2 µg/m³, evening PM2.5: 132.8 ± 19.2 µg/m³), reflecting its semi-urban character and reduced industrial activity, in line with Etchie et al. (2018).

Sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) also exhibited temporal increases. As presented in (Table 1 and Table 2), SO_2 at Eneka rose from 0.145 ± 0.03 ppm in the morning to 0.172 ± 0.04 ppm in the evening, while NO_2 increased from 0.158 ± 0.02 ppm to 0.182 ± 0.03 ppm. Similar patterns were observed across other locations, though Bori consistently recorded the lowest values. Elevated SO_2 and NO_2 levels in Eneka and Igbo-Etche suggest strong contributions from fossil fuel combustion, industrial emissions, and vehicular traffic (Abam & Unachukwu, 2017; Akinbile & Yusoff, 2011). Even in Bori, the presence of these pollutants indicates contributions from biomass burning and small-scale combustion, consistent with Kandji et al. (2006). These pollutants are precursors to acid rain and smog, with long-term exposure linked to respiratory and cardiovascular diseases (Chen et al., 2018; WHO, 2021).

Carbon monoxide (CO) and volatile organic compounds (VOCs) concentrations were highest at Eneka, with evening values reaching 13.8 ± 2.3 ppm and 1.40 ± 0.18 ppm, respectively (Table 2). These levels reflect emissions from vehicles, industrial processes, and open burning (Anuforom et al., 2019). In contrast, Bori recorded the lowest CO (10.2 ± 1.6 ppm morning; 12.4 ± 2.0 ppm evening) and VOCs (0.80 ± 0.11 ppm morning; 1.18 ± 0.15 ppm evening). The strong correlation between CO, VOCs, and particulate matter suggests incomplete combustion as a major source of pollution, corroborating Fawole et al. (2016). Elevated VOC levels in Eneka are particularly concerning, as they exceed values reported in South African urban areas (<1 ppm) (Kampa & Castanas, 2008), highlighting regional disparities in industrial regulation and enforcement.

The contamination factor (CF) and degree of contamination (DC) analysis further illustrate the severity of pollution. As shown in (Table 3), Eneka recorded the highest CF values across pollutants, with evening CF values of 12.39 (PM2.5), 11.64 (PM10), 57.33 (SO_2), and 27.6 (CO). Correspondingly, its DC rose from 18.38 (morning) to 22.01 (evening) (Table 4), categorizing it as moderately contaminated. Igbo-Etche followed closely, with DC values of 17.31 (morning) and 20.82 (evening). Bori consistently recorded the lowest DC values (16.06 morning; 19.44 evening), reflecting its relatively cleaner environment. Oyigbo and Rukpokwu exhibited intermediate contamination levels, with DC values ranging between 16.74–21.48, indicating moderate pollution exposure. The consistent increase in DC from morning to evening across all sites highlights the role of reduced atmospheric dispersion and heightened evening emissions (Kumar et al., 2020).

The observed pollutant levels pose significant health risks. PM2.5, capable of penetrating deep into the lungs and bloodstream, is linked to respiratory and cardiovascular diseases (Liu et al., 2020). Elevated SO_2 and NO_2 exacerbate respiratory irritation and contribute to smog formation, while CO impairs oxygen delivery, increasing cardiovascular risks (Park & Lee, 2018). VOC exposure is associated with neurological effects, organ damage, and carcinogenic risks (Anderson et al., 2021). Vulnerable populations children, the elderly, and individuals with pre-existing conditions are disproportionately affected (Guarnieri & Balmes, 2014). Without effective mitigation, the cumulative health burden of air pollution in Rivers State will continue to escalate, consistent with findings by Adebayo et al. (2020) and Efe (2013).

Comparatively, the pollutant levels observed mirror patterns in other African cities. PM10 levels in Eneka (232.8 µg/m³ evening) are comparable to those reported in Accra, Ghana (150–250 µg/m³) (Arku et al., 2015). Similarly, SO_2 and NO_2 levels parallel those documented in Nairobi, Kenya (Kandji et al., 2006). However, VOC concentrations in Eneka exceed those reported in other African contexts, highlighting localized industrial practices and regulatory gaps. These findings emphasize the urgent need for stricter emission controls, improved urban planning, and public health interventions to mitigate the growing air pollution crisis in Rivers State, in line with recommendations from UNEP (2019), NESREA (2019), OECD (2022), USEPA (2018), and WHO (2010, 2021). The broader implications of these findings resonate with global studies linking air pollution to increased morbidity and mortality (Guarnieri & Balmes, 2014; Kampa & Castanas, 2008; Zhang et al., 2019). The evidence presented here underscores the necessity of coordinated policy responses, integrating environmental monitoring, regulatory enforcement , and community-level

Table 1: Air Quality Parameters observed in the Morning.

	Eneka	Igbo-Etche	Bori	Oyibgo	Rukpokwu
PM2.5 (µg/m³)	128.5 ± 18.6	122.4 ± 17.8	112.4 ± 16.2	125.6 ± 18.2	116.8 ± 16.9
PM10 (µg/m³)	202.4 ± 29.5	189.6 ± 27.4	176.5 ± 25.6	196.4 ± 28.5	182.5 ± 26.4
SO_2 (ppm)	0.145 ± 0.03	0.138 ± 0.03	0.128 ± 0.02	0.142 ± 0.03	0.134 ± 0.02
NO_2 (ppm)	0.158 ± 0.02	0.152 ± 0.02	0.142 ± 0.02	0.155 ± 0.02	0.146 ± 0.02
CO (ppm)	11.6 ± 1.9	10.8 ± 1.7	10.2 ± 1.6	11.4 ± 1.8	10.5 ± 1.7
VOCs	1.00 ± 0.13	0.90 ± 0.12	0.80 ± 0.11	0.94 ± 0.13	0.86 ± 0.12

Table 2: Air Quality Parameters observed in the Evening.

	Eneka	Igbo-Etche	Bori	Oyibgo	Rukpokwu
PM2.5 (µg/m³)	148.7 ± 21.8	142.6 ± 20.4	132.8 ± 19.2	145.8 ± 21.2	136.4 ± 19.8
PM10 (µg/m³)	232.8 ± 33.6	218.5 ± 31.2	204.4 ± 29.5	226.5 ± 32.8	212.6 ± 30.7
SO_2 (ppm)	0.172 ± 0.04	0.162 ± 0.04	0.152 ± 0.03	0.168 ± 0.04	0.158 ± 0.03
NO_2 (ppm)	0.182 ± 0.03	0.172 ± 0.03	0.162 ± 0.03	0.178 ± 0.03	0.168 ± 0.03
CO (ppm)	13.8 ± 2.3	13.2 ± 2.1	12.4 ± 2.0	13.6 ± 2.2	12.8 ± 2.1
VOCs	1.40 ± 0.18	1.31 ± 0.18	1.18 ± 0.15	1.33 ± 0.18	1.25 ± 0.18

Table 3: Contamination Factor in the Morning and Evening.

Location	Time	PM2.5 (µg/m³)	PM10 (µg/m³)	SO_2 (ppm)	NO_2 (ppm)	CO (ppm)	VOCs
Eneka	Morning	10.71	10.12	48.33	7.90	23.2	10.0
	Evening	12.39	11.64	57.33	9.10	27.6	14.0
Igbo-Etche	Morning	10.20	9.48	46.00	7.60	21.6	9.0
	Evening	11.88	10.93	54.00	8.60	26.4	13.1
Bori	Morning	9.37	8.83	42.67	7.10	20.4	8.0
	Evening	11.07	10.22	50.67	8.10	24.8	11.8
Oyigbo	Morning	10.47	9.82	47.33	7.75	22.8	9.4
	Evening	12.15	11.33	56.00	8.90	27.2	13.3
Rukpokwu	Morning	9.73	9.13	44.67	7.30	21.0	8.6
	Evening	11.37	10.63	52.67	8.40	25.6	12.5

Table 4: Degree of Contamination (Morning and Evening).

Location	Morning	Evening
Eneka	18.38	22.01
Igbo-Etche	17.31	20.82
Bori	16.06	19.44
Oyigbo	17.93	21.48
Rukpokwu	16.74	20.20

interventions to reduce exposure and safeguard public health (World Bank, 2018).

Conclusion

This study provides a comprehensive assessment of air quality conditions around plastic waste dumping and incineration sites in selected residential areas of Port Harcourt, namely Eneka, Igbo-Etche, Bori, Oyigbo, and Rukpokwu. The findings clearly demonstrate that the concentrations of major air pollutants including $PM_{2.5}$, PM_{10}, SO_2, NO_2, CO, and VOCs—substantially exceed the permissible limits recommended by the World Health Organization (WHO). Such elevated pollutant levels represent a significant environmental and public health concern, particularly for residents living in close proximity to these waste disposal and burning sites. The study therefore highlights the environmental implications of uncontrolled plastic waste management practices in rapidly urbanizing cities. Among the pollutants examined, particulate matter ($PM_{2.5}$ and PM_{10}) exhibited the most alarming concentrations, far exceeding international health guidelines. The persistence of these fine particles in the atmosphere is particularly dangerous because of their ability to penetrate deep into the respiratory tract and even enter the bloodstream. Prolonged exposure to these particles increases the risk of respiratory diseases, cardiovascular disorders, and other chronic health conditions. The elevated levels recorded in this study

suggest that residents, especially vulnerable populations such as children, the elderly, and individuals with pre-existing respiratory conditions, are at heightened risk of adverse health outcomes. The concentrations of gaseous pollutants such as sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) also surpassed WHO recommended thresholds, with noticeable temporal variations observed during evening periods. These increases are likely linked to intensified human activities, including industrial operations, vehicular emissions, and waste burning. Beyond their direct toxicological effects on human health, these gases also contribute to secondary atmospheric reactions that produce additional particulate matter and ground-level ozone, thereby compounding air quality deterioration and further aggravating respiratory health problems in exposed populations.

Similarly, carbon monoxide (CO) concentrations were found to be consistently elevated, particularly in the Eneka sampling location. This trend is indicative of incomplete combustion processes associated with the burning of mixed municipal waste, including plastics. The presence of high CO levels poses serious physiological risks, as carbon monoxide interferes with the blood's oxygen-carrying capacity, potentially leading to hypoxia, cardiovascular stress, and, in extreme cases, fatal poisoning. The findings therefore underscore the hazardous consequences of uncontrolled waste incineration practices in residential environments. In addition, the detection of volatile organic compounds (VOCs) at concentrations exceeding both WHO and European Union (EU) standards highlights another critical dimension of air pollution in the study area. VOCs are known for their toxic and carcinogenic properties and are commonly released during the combustion of plastic materials and other synthetic wastes. Their elevated presence in the ambient environment suggests prolonged exposure risks for local populations, including potential long-term health effects such as cancer, neurological disorders, and chronic respiratory illnesses. Spatial and temporal variations in pollutant concentrations further reveal that areas closer to industrial activities and waste burning sites experience higher levels of contamination. These variations emphasize the influence of anthropogenic activities and environmental factors on local air quality dynamics. The results therefore reinforce the importance of sustained environmental monitoring and the implementation of targeted pollution mitigation strategies to reduce exposure levels in affected communities. When compared with similar studies conducted in other African metropolitan centers such as Lagos, Cairo, and Accra, the results from Port Harcourt reflect a broader pattern of environmental challenges associated with poor waste management systems, rapid urban expansion, and insufficient regulatory enforcement. These findings confirm that air pollution resulting from plastic waste disposal and incineration remains a critical urban environmental issue across many developing cities. Overall, this study contributes to the growing body of evidence highlighting the environmental and public health consequences of inadequate waste management and uncontrolled plastic burning. The elevated levels of particulate matter, toxic gases, and volatile organic compounds recorded in this research underscore the urgent need for integrated environmental policies, improved waste management infrastructure, and continuous air quality monitoring systems. Addressing these challenges will require coordinated efforts among government agencies, environmental regulators, public health institutions, and local communities to ensure sustainable urban development and safeguard the health of residents in Port Harcourt and similar urban environments.

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