SEASONAL VARIATIONS IN PARTICULATE MATTER EMISSIONS FROM MUNICIPAL SOLID WASTE DUMPSITES IN ONITSHA, ANAMBRA STATE, NIGERIA

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Abstract

This work studied the seasonal variations in particulate matter emissions from municipal solid waste dumpsites in Onitsha, Anambra State, Nigeria. The study was field based where portable multi-parameter sampling device (air quality monitor, aqm-388 model) was used to obtain the data on air quality parameter. The result showed that variations in the concentrations of $pm_{1.0}$ exhibit highly significant differences ($p < 0.01$) across the seasons. The observed $pm_{2.5}$ levels exhibit highly significant differences ($p < 0.01$) across the seasons. The observed pm_{10}levels did not differ significantly across the seasons ($p > 0.05$). The level of three of particulate matter including $pm_{1.0}$, $pm_{2.5}$ and pm_{10} differ across the dumpsites and the variations did not follow the same pattern. Seasonal influences played a significant role. The study reveals significant concentrations of particulate matter, highlighting the waste sector's substantial contribution to global emissions. The work recommended that there is need to encourage collaborative efforts among stakeholders, including government bodies, environmental agencies, local communities, and waste management organizations, to collectively address the challenges posed by greenhouse gas emissions from dumpsites.

Keywords: Seasonal Variations, Particulate Matter, Dumpsite, Municipal Solid Waste, Emissions

Introduction

In Nigerian cities, the common technique of solid waste disposal is through open dump often located by the side of the highway at the peripheral parts of cities and slums, without bearing in mind the possible health hazards or the effect these actions would have on the aesthetic values of the locations (Onwughara *et al.,* 2010). Often, the volume of waste that accumulates in a couple of hours often overwhelms the waste collectors, they are often more than what the collectors can evacuate in a day.

The effect of poor management of municipal solid waste in quite some countries of the world especially urban areas of developing countries, is now a global concern. It has a multi-facet negative effect on the environment and continued existence of human beings. The intense increase in the volume and types of wastes necessitated by the ever-increasing population growth and accompanying urbanization and industrialization pose serious threat to the environment (Nanda and Berruti, 2021). Globally, it is estimated that 2.01billion metric tonnes of municipal solid wastes are

produced annually and is expected to rise by two-folds in 2050, which is a cause for concern in the future (Gautam and Agrawal, 2021).

There are several gaseous pollutants that originate from municipal solid waste dumpsites such as greenhouse gasses (CO_2, CH_4, O_3), formaldehyde, NO_x, SO_2 and particulate matter. Among the other pollutants originating from MSW dumpsites are particulate matters (PM_1, $PM_{2.5}$ and PM_{10}). High atmospheric particulate matter contents alter the quantity and quality of light reaching the earth surface and may contribute significantly to global warming (Chen *et al*., 2020). They also interact with NO_2, SO_2 to form nitrates and sulphates which interfere with the refractivity of light and subsequently contribute to global warming (Zhou *et al.*, 2020). An inclusion of particulate matter composition of MSW emissions will throw more light on the role of MSW in the onset and progression of greenhouse phenomenon.

Yang *et al.* (2024) noted that since the last century, researchers associated with particulate formation, emission and control have appealed to extensive scientific attention as a result of human health and environmental problems associated with particulate pollution. According to Yang *et al.* (2021) the harmfulness of particulate matter becomes more intense as the particle size reduces, thereby pushing emphasis on submicron particulate matter. Thompson (2018) and Yang *et al.* (2021) identified particulate matter as one of the large pollutants emitted during the burning of municipal solid waste. Wastes accumulated in municipal solid waste dumpsites are burnt so as to reduce the volume of waste even though it is not an environmentally friendly method, and as a result of lack of newer and greener treatment techniques, burning of wastes are used in most countries globally (Chen *et al.*, 2017).

Barkhordari *et al.* (2021) collected 15 samples every six days from each of 9 points selected to study the processes taking place in dumpsites (135 particulate matter samples total). Examining the concentration and size fraction of particulate matter (i.e., PM_1, $PM_{2.5}$ and PM_{10}) is an essential issue to notify policy makers about the health impacts on exposed residents. The results of this work showed that a negative correlation between temperature and particulate matter size followed the order $PM_{10} > PM_{2.5} > PM_1$.

Angaye and Abowei (2018) investigated the seasonal impacts of Suspended Particulate Matter (SPM), associated with 4 Household Municipal Solid Wastes dumpsites (MSWs), and two stations in the central MSWs dumpsite in Yenagoa Metropolis. The SPM values were monitored at levels PM1, PM2.5, PM4, PM7, PM10 and Total Suspended Particulate. Results showed that the dumpsites were polluted in dry season and fairly clean in wet season.

Soil erosion is a well-known environmental problem in South Eastern Nigeria. It is the removal of soil particles from the surface of the Earth by natural processes, transportation and deposition of the particles by the action of wind, heat and water. Onyegbule (2005) described soil erosion as the process whereby the surface layer of the soil is detached and carried by agents of denudation and a lower layer in the soil is exposed leaving a topographic roughness on the resulting landscape.

Statement of the problem

Among the pollutants originating from MSW dumpsites are particulate matters (PM_1, $PM_{2.5}$ and PM_{10}). High atmospheric particulate matter contents alter the quantity and quality of light reaching the earth surface and may contribute significantly to global warming (Chen et al., 2020). They also interact with NO_2, SO_2 to form nitrates and sulphates which interfere with the refractivity of light

and subsequently contribute to global warming (Zhou et al., 2020; Chen et al., 2021). An inclusion of particulate matter composition of MSW emissions will throw more light on the role of MSW in the onset and progression of greenhouse phenomenon in the study area.

The concentration of MSW emissions from dumpsite is dependent on the residence period in the air within the environment of the dumpsite, this residence period is influenced by environmental factors like seasonality. With the growing awareness of the contribution of municipal solid waste emissions on the inception and evolution of global warming and given the many heaps of MSW at different locations in Onitsha, there is the need for quantitative evaluation of particulate matter emissions from solid waste dumpsites in selected towns in the study area.

Description of the formation

The Ebenebe sandstone is one of the three constituent sandstone members that make up the Paleocene Imo formation which is the oldest Paleogene lithostratigraphic unit of the Niger Delta basin; the other two members are the Igbada sandstone and Umuna sandstone (Odumodu, 2013). The sandstone of Ebenebe outcrops at Ugwuoba, Umuogbuefi-Ebenebe and Isiagu respectively (Ohwona and Okoro, 2022). They consist of fine-coarse grained sandstone, coarse fine grained sandstone, mudstone and siltstone. It's believed that the erosion of the Ebenebe formation began in the Quaternary period, which started around 2.6 million years ago. As this was a time of dramatic climate changes, including the transition from a wet and humid climate to a drier and cooler climate, the changing climate is thought to have led to increased erosion, as well as the deposition of windblown loose sediments on top of the formation. The erosion has likely been accelerated in more recent times due to human activities etc.

The study was conducted in Anambra State, located in the southeastern region of Nigeria, which approximately lies between 6.1460° N latitude and 6.7869° E longitude. Two dumpsites were selected for sampling at Onitsha, they were located along Owerri Road and Nkwelle Ezunanka. The topography of Anambra State is characterized by a mix of lowlands and plateaus, offering a diverse landscape. The southern part of the state consists of coastal plains and river valleys, while the northern region features more elevated terrain and hills.

The landscape is predominantly influenced by the Niger River, which flows through the western part of the study area (NPCN, 2006). Onitsha experiences a tropical climate, with two distinct seasons: the wet season and the dry season. The wet season typically occurs from April to October, with the peak rainfall usually happening in June and September. During this period, the state receives substantial amounts of rainfall, contributing to the fertility of its soils and supporting agriculture. The dry season, on the other hand, takes place from November to March. During this period, the rainfall decreases significantly, and the state experiences dry and dusty conditions. Temperatures in Anambra State remain relatively stable throughout the year, with average highs ranging from 28°C to 32°C (82°F to 90°F), (Onwuemesi, and Nwankwoala. 2013).

Onitsha is one of the busiest commercial cities in Nigeria and West Africa. The city is known for its vibrant markets, attracting traders and buyers from various parts of Nigeria and neighboring countries. The main market in Onitsha, known as Onitsha Main Market, is one of the largest open markets in West Africa. It is a major trading center for various goods, including textiles, electronics, foodstuffs, and consumer products. Trade and commerce are the backbone of Onitsha's economy and play a crucial role in the city's growth and development (Okoli, 2015).

Methodology

The study was field based where portable multi-parameter sampling device (Air Quality Monitor, AQM-388 model) was used to obtain the data on air quality parameter (particulate matter). Data needs for the study include numeric data on atmospheric concentrations of $PM_{1.0}$, $PM_{2.5}$ and PM_{10}, the particulate matters were determined in µg/m³.

Integrated (composite) sampling was used in collecting samples, over an extended period to obtain an average representation of particulate matter. Two MSW dumpsites were randomly selected. At each sampling site, five (5) sampling points of equal distance round about the dumpsite were selected. The values from each of the five different positions (P1-P5) were averaged to obtain the value which represented the composite value for each parameter. Readings were taken in triplicates twice each day. Data were obtained for a duration of one year.

Result

Table 1: Concentrations of particulate matter emissions in the study area

Particulate Matter	Conc. $\bar{\times}$±SD (Min-Max)
$PM_{1.0}$	8.10^{b} ±5.69 (0.00-47.00)
$PM_{2.5}$	28.85^{b} ±13.91 (19.00-246.00)
PM_{10}	34.43^{b} ±20.97 (6.00-332.00)

Superscripts = levels of significant difference across the concentrations for the particulate matter emission. Values with letter alphabet superscript were significantly different between concentrations at $p < 0.05$.

The levels of PM 1.0 exhibited a highly significant difference ($p < 0.01$), with mean values from each dumpsite significantly differing ($p < 0.05$) from one another. PM 1.0 emissions from. Though these levels remained below the WHO and FEPA standard of 250 µg/m³.

PM 2.5 emissions from dumpsites in the study area differed highly significantly ($p < 0.01$), with the variance originating from the mean value recorded. The mean concentrations of PM 2.5 in the study area was 28.85 µg/m³ and PM 2.5 emission levels did not align favorably with WHO and FEPA standards.

Atmospheric levels of PM 10 from dumpsite vicinities across the dumpsites exceeded the WHO and FEPA recommended limit of 20 mg/m³. PM 10 emissions from dumpsites differed significantly ($p < 0.05$).

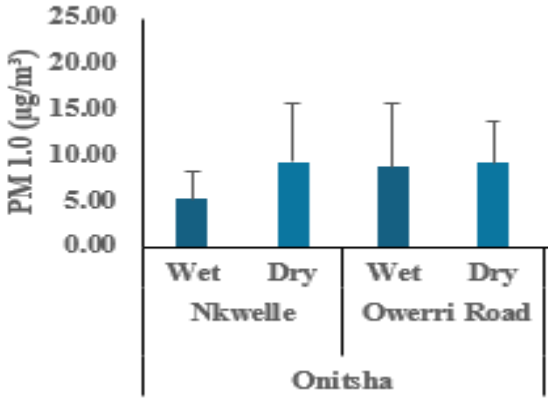

Figure 1: Seasonal variation in the levels of $PM_{1.0}$ in the study area

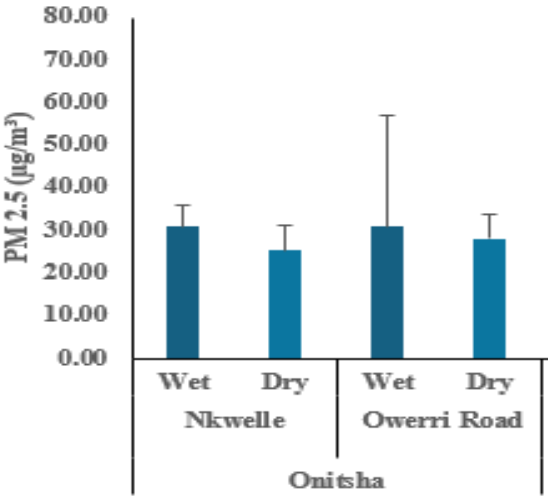

Figure 2: Seasonal variation in the levels of $PM_{2.5}$ in the study area.

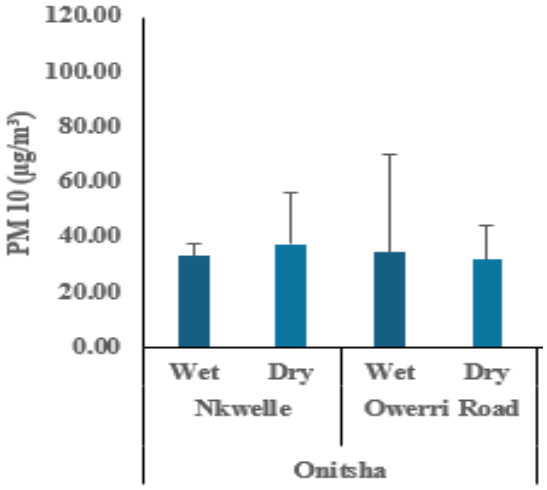

Figure 3: Seasonal variation in the levels of PM_{10} in the study area

Discussion

Seasonal variations in the concentration of particulate matter

$PM_{1.0}$: Variations in the concentrations of $PM_{1.0}$ exhibit highly significant differences ($p < 0.01$) across the seasons, with higher concentrations recorded during the dry season than the wet season. Figure 1 illustrates the seasonal variations in PM 1.0 emission levels from dumpsites across the study area.

PM 2.5: Figure 2 depicts the seasonal variations in $PM_{2.5}$ levels at the dumpsite vicinity across the study area. The observed $PM_{2.5}$ levels exhibit highly significant differences ($p < 0.01$) across the seasons, with higher values recorded in the wet season compared to the dry season. Day variations in $PM_{2.5}$ levels were not found to be significant ($p > 0.05$).

PM 10: Figure 3 illustrates the seasonal variations in PM_{10} levels at the dumpsite vicinity across the study area. The observed PM_{10}levels did not differ significantly across the seasons ($p > 0.05$). Day variations in PM_{10} levels were not found to be significant ($p > 0.05$).

The level of three of particulate matter including $PM_{1.0}$, $PM_{2.5}$ and PM_{10} differ across the dumpsites and the variations did not follow the same pattern. Seasonal influences played a significant role, particularly affecting $PM_{1.0}$ and $PM_{2.5}$, while PM_{10} exhibited relative stability throughout the seasons. All these variations, underscores the multifaceted nature of particulate matter and its diverse sources.

The application of principal component analysis shed light on the fundamental role of variations in PM 1.0 and PM 10 as significant variables contributing to the overall dataset variations. This analytical approach emphasized the importance of these particulate matter categories in understanding the comprehensive dynamics of the studied environmental conditions. Comparisons with prior studies, such as Richard et al. (2019), revealed similarities in the ranges of $PM_{1.0}$ and $PM_{2.5}$, showcasing a degree of consistency in observations. This alignment with previous research strengthens the reliability and validity of the current findings.

Similarly, the study's reported values for PM_{10} fell within the range documented by Efe and Efe (2008), who examined the spatial distribution of particulate air pollution in Nigerian cities. This study also noted that seasonal variations in particulate matter levels, as reported by Richard et al. (2019), did not exhibit substantial differences. This finding implies a certain level of consistency in the seasonal patterns of particulate matter distribution across different regions, emphasizing the need for comprehensive and region-specific investigations to capture the nuanced variations. Particulate matter, with its diverse physical, chemical, and morphological characteristics, originates from both anthropogenic and natural sources. These particles can form secondary inorganic and organic particles, as highlighted by Soile *et al.* (2018). The comprehensive nature of particulate matter composition, including

components such as chloride, nitrate, ammonium, sulphate, 68 chemical elements, and endotoxins, highlights the complexity of the environmental factors under consideration.

Conclusion and Recommendation

The research emphasizes the need for collective efforts in developing nations like Nigeria to address emissions from municipal solid waste dumpsites, particularly focusing on a specific area. The study reveals significant concentrations of particulate matter, highlighting the waste sector's substantial contribution to global emissions. Data from various dumpsites hold implications for effective management strategies, with observed variations in emissions emphasizing the necessity for tailored mitigation efforts due to diverse spatial and seasonal conditions.

Particulate matter levels, including $PM_{1.0}$, $PM_{2.5}$ and PM_{10}, exhibit significant variability across dumpsites, influenced by seasonal factors and diverse sources. Multivariate tests highlight the importance of $PM_{1.0}$ and PM_{10} as significant variables contributing to overall dataset variations. These observations underscore the need for region-specific investigations to capture nuanced variations in particulate matter distribution, emphasizing the complexity of environmental factors originating from both anthropogenic and natural sources.

In conclusion, this research accentuates the imperative for concerted collaborative efforts in developing nations, with a particular emphasis on Anambra State Nigeria, to tackle the pressing issue of emissions originating from municipal solid waste dumpsites. This study's observations bring to light substantial concentrations of emissions, underscoring the significant role played by the waste sector in contributing to global emissions. The data derived from multiple dumpsites not only underscore the severity of the problem but also carry profound implications for devising effective management strategies.

In essence, the study advocates for a comprehensive and area-specific approach to waste management, considering the distinctive features of each locality. The urgency for collaborative endeavours is grounded not only in the immediate environmental concerns but also in the broader context of global environmental sustainability. By emphasizing the need for specific attention to municipal solid waste dumpsites and their emissions, the research serves as a catalyst for informed policymaking and targeted interventions, aiming to alleviate the environmental impact and health risks associated with gaseous emissions from waste disposal.

There is need to encourage collaborative efforts among stakeholders, including government bodies, environmental agencies, local communities, and waste management organizations, to collectively address the challenges posed by greenhouse gas emissions from dumpsites. It is also important to develop and implement targeted mitigation strategies that take into account the diverse spatial and seasonal conditions observed across different dumpsites. It is crucial to integrate socio-economic factors, including differences in socio-economic status and educational levels, into waste management strategies across the various metropolis. This would promote comprehensive waste management practices that consider the composition of the waste stream and encourage the adoption of sustainable waste disposal methods to minimize environmental impact.

There is need to raise public awareness about the health risks associated with specific pollutants, particularly $PM_{2.5}$, and implement protective measures for vulnerable populations, including dumpsite workers and nearby residents. This may involve the

provision of appropriate personal protective equipment and health education.

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