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Environmental Impact of Solid Waste Generation on Air Quality in Ebonyi State, Nigeria

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ABSTRACT

Background and Objective: The emission of pollutants during the process of solid waste management is of great concern due to its hazardous effect on air quality. The study aimed to examine the environmental impact of solid waste generation on air quality in Ebonyi State, Nigeria. **Materials and Methods:** Sensitive digital monitors were used to monitor the levels of CH_4, H_2S, NO_2, CO and $PM_{2.5}$ from the three dumpsites and a control. The ambient air quality was compared to standards set by the World Health Organisation. Data sets were analyzed using Fisher's Significance Least Difference (F-LSD) at the 0.05 probability level. **Results:** The selected study area had a high concentration of potentially dangerous contaminants, which contributed to the poor environmental air quality around waste dumps. The study's findings revealed that while CH_4 is within the recommended guidelines, CO, NO_2, H_2S, and $PM_{2.5}$ concentration levels in the atmosphere were found to have exceeded WHO regulation guidelines. The level of $PM_{2.5}$ increased downwind instead of at the source site. The amount of greenhouse gases and $PM_{2.5}$ in the atmosphere was also influenced by the weather. In Ebonyi State, the Ogoja Road, New Layout and Kpirikpiri are highly populated. Residents who live close to waste dump sites are very concerned about the quality of the surrounding air. **Conclusion:** Therefore, it is necessary to continuously monitor the air quality in Ebonyi State, Nigeria, particularly around solid waste dumps, to prevent harmful air pollution and ensure the safety of the people.

KEYWORDS

Municipal solid waste, disposal sites, environment, greenhouse gases, meteorological parameters, particulate matter

INTRODUCTION

Because of the daily population growth that has occurred so quickly, particularly in developing countries, the issue of solid waste production has grown from a local, regional and national concern to one that affects the entire world and poses risks to the environment and public health[1]. Massive production of solid waste has led to a significant environmental issue that is endangering human and animal health and impeding development. Inadequate municipal waste management plagues a lot of developing nations' cities, leading to issues that harm both human and animal health as well as economic and environmental losses[1].

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When one or more pollutants, such as particulate matter, gases, fog, smoke, vapour or scents, are present in the atmosphere for an extended period of time and in such high concentrations that they injure people, plants, animals or property, they are considered to be an undesirable source of air pollution[2]. Numerous negative effects of air pollution include soil deterioration, loss of vegetation and biodiversity, damage to materials and structures and more[3]. Modern cities experience air pollution due to the atmospheric air purification system's inability to handle the massive amounts of chemicals released into the environment[4]. Air quality is highly important if lessen the health hazards connected with its effects, such as catarrh, asthma, irritation of the nose and eyes, blindness and death[5,6]. Little or no attention is paid to environmental quality in Abakaliki, as it is in other Nigerian towns and around the world[7].

Numerous studies have discovered strong evidence of the risks posed by solid waste production and disposal, which affect plant life globally and cause irreversible erosion processes unless the current land use pattern is changed[8]. Low plant productivity is caused by solid waste pollutants, which have external effects on the soil and alter its physicochemical characteristics. The level of fermentation, alkaline, acid and oxidative degradation conditions, as well as the presence of organic matter, all have an impact on the chemical element accumulation in plants[8]. This influence extends beyond the soil's overall composition. As a result of their inability to afford the construction of landfills, developing nations run a serious risk of having waste dumped on their soil[8]. Every day in Abakaliki, hundreds of tonnes of solid waste are generated, much of it ending up in open dumps that contaminate groundwater and surface water and pose serious health risks[9]. Due to poor administration, physical ineptitude or inefficiency, technical malfunctions or inadequate waste management budgets, the majority of the waste generated in Abakaliki is not collected by the municipal collection system[9].

A number of factors, such as the absorption or release of various harmful gases such as VOCs, particulates, dust, H_2S, CO, NO_2, methane, NH_3 and sulphur dioxide, are responsible for improper waste treatment and disposal polluting the air[9]. Air pollution is the release of particulate matter, biological molecules or other potentially harmful elements into the atmosphere that harm humans, other living things like plants and animals, or the environment[9]. Cities' improper management of solid waste generation has led to significant environmental issues. The major environmental concerns in the world today, including Abakaliki, Ebonyi State and numerous open dumping sites, are due to the open dumping and burning of solid municipal waste (MSW), suspended particulate matter (SPM), suspended particulate matter, Sulphur Dioxide (SO_2), Nitrogen Dioxide (NO_2), Carbon Monoxide (CO), Methane (CH_4) and other related harmful gases[10]. Environmental pollution is defined as the introduction of any material or form of energy (such as heat and noise) into the environment at a rate greater than the ecosystem's capacity to absorb, disperse, or disintegrate it[10]. This can be harmful to biotic systems, which include plants, animals and other living things[10]. Therefore, the study aimed to determine the environmental impact of solid waste generation on air quality in Ebonyi State, Nigeria.

MATERIALS AND METHODS

Study area: The study was conducted in Nigeria's Ebonyi state capital, Abakaliki from February to November, 2023. It is situated at Latitude 6'19°N and Longitude 8°6'E in Southeast Nigeria's Savannah region. It has a total area of 5,670 square kilometers and 141,438 inhabitants[11]. Typically, the setting is on a hilly plateau[12]. Its temperature, which ranges from 270 to 310°C, is comparatively high. The study area experiences two distinct rainfall patterns in August, both of which are brief (April to July and September to November)[13]. The soil of the study area is ultisol[10].

Materials: Carbon Monoxide (CO), Hydrogen Sulphide (H_2S), Ammonia Oxide (CH_4), Nitrogen Oxide (NO_2) and Particulate Matter ($PM_{2.5}$) levels were measured in the air utilizing sensitive digital monitors.

The following instruments were used to keep track of the samples:

Carbon Monoxide (CO): With an alarm set, a hand-held carbon monoxide gas monitor, model 19256H, was utilized to detect CO concentrations in the range of 0-500 μg/m^3.

Nitrogen Dioxide (NO_2): The hydrogen sulphide interactions between 0 and 10 μg/m^3 per set were detected using the portable GASMAN nitrogen dioxide gas monitor 19835H model with alarms.

Hydrogen Sulphide (H_2S): The portable GASMAN hydrogen sulphide gas monitor 19504H model with an alert set was used to detect hydrogen sulphide interactions at a distance of 0–50 μg/m^3.

Methane (CH_4): With set-off alarms, the GASMAN hand-held methane gas monitor 19736H was used to get a gas concentration of 0-50 μg/m^3.

Particulate Matter ($PM_{2.5}$): Riken Keiki $PM_{2.5}$ monitor model NP-237H with alarm.

Sample procedure: To determine the environmental air quality around the study area, three waste dumpsites (New Layout Dumpsite, Kpirikpiri Dumpsite and Ogoja Road Dumpsite) were visited in 2023 to measure the following potential gases or pollutants: CO, NO_2, CH_4 and H_2S. The typical size of a New Layout Dumpsite is 50 ha, with a 30 ha covered zone. Just four of the eight plots, which produced between 4,000 and 4,500 ton of solid waste every day, have been productive since 2019. Since 1999, Kpirikpiri Dumpsite has served as a disposal location. It stopped operating in 2017 after processing 9 million tonnes of waste materials. The Ogoja Road Dumpsite processed two thousand tonnes of solid waste each day using about twenty canals. The New Layout Dumpsite engages in mechanical earth leveling, sorting, unloading, transportation and waste compaction. Ogoja Road Dumpsite displayed the process of loading and unloading, logistics of transport and waste material sorting, while Kpirikpiri Dumpsite displayed no specific activity other than transportation.

However, the monitors' detection times for pollutants were set to the manufacturer's suggested range of 0-500 μg/m^3 and an alarm was set for a specific time to start the measurement. Hourly measurements were made in both the sample and control locations. Each analyzed parameter was recorded at a separate sample location for each of the ten weeks of the study, which lasted for two weeks, three weeks, four weeks, six weeks, eight weeks and ten weeks. All readings were taken at three different waste dumpsites and on farmland used as a control by Alex Ekwueme Federal University, Ndufu Alike, Ebonyi State, Nigeria. The $PM_{2.5}$ levels were recorded simultaneously at the source and 50 m away (downwind) from the source using devices positioned 1.5 m above ground level. The ambient integration of these gases; NO_2, CO, H_2S, CH_4 and $PM_{2.5}$ has compared to[15] recommendations. Concentration levels that are above the regulatory standard are therefore regarded as being extremely polluted and hazardous to the local inhabitants.

Data analysis: Data were analysed by using researchers[16,17] analytical methods and the significant means of the parameters of all the soil samples from all the sampling points were differentiated using Fisher's Least Significant Difference Test (FLSD) at the 5% level ($p<0.05$) of probability. At each sampling location, a regression and correlation analysis was conducted to examine the relationship between $PM_{2.5}$ and greenhouse gases as well as meteorological parameters.

RESULTS AND DISCUSSION

Methane (CH_4) gas concentration (μg/m^3): The mean results for Methane (CH_4) are shown in Table 1. In Ogoja Road Dumpsite, the lowest level of CH_4 was recorded in Point A with 7.12 μg/m^3, compared to 9.00, 15.30 and 18.02 μg/m^3 recorded in Points B, C and D.

The CH_4 mean result obtained in the New Layout Dumpsite showed a higher level of 19.02 μg/m^3 CH_4 in Point A than in Points B, C and D, which recorded 17.75, 14.30 and 11.00 μg/m^3 CH_4.

In Kpirikpiri Dumpsite, CH_4 decreased from Points A, B, C and D with 11.74, 14.09, 18.43 and 20.00 μg/m^3, respectively, while Point D recorded the highest CH_4 of 20.00 μg/m^3.

At the University Farm, a uniform concentration level of 0.00 μg/m^3 was observed at all sample points.

However, all the locations were significantly different and also below the[15] recommended permissible limit of 1000 μg/m^3.

The high concentration of Methane (CH_4) in all of the waste dumpsites studied could be attributed to biological decomposition[18]. A value of 0.00 μg/m^3, which is recorded in control, is regarded as local waste. Methane has no odour and is lighter than air. It is a significant greenhouse gas and because of its lightness, it tends to ascend and gather towards the higher, stagnant areas of enclosed structures and tightly closed manure storage pits[18]. Greenhouse gases are generated when microbial activity breaks down organic substances in the waste product[19]. Therefore, it is believed that the dumpsites are significant sources of emissions of CO, H_2S, NO_2 and CH_4. With a potential for 25 times more global warming than CO, H_2S and NO_2, CH_4 is a significant contributor to greenhouse gases[20,21]. A study conducted at Rumuolumeni Port Harcourt (Nigeria) found that the concentration of CH_4 was lower than our recorded levels, ranging from 0.16 to 0.21 μg/m^3 at two distinct locations within a disposal site[22].

Hydrogen sulphide (H_2S) gas concentration (μg/m^3): The highest hydrogen sulphide concentrations were found at Points A and D at the Ogoja Road Dumpsite, as shown in Table 2, with concentration levels of 25.02 and 30.00 μg/m^3, respectively. The lowest concentration levels were found to be 19.23 and 13.17 μg/m^3 at Points C and D, respectively.

The maximum H_2S concentration level at the New Layout Dumpsite was found to be 17.19 μg/m^3 at Point D, while others were found to be lower at Points A, B and C, with 12.00, 12.10 and 15.02 μg/m^3, respectively.

Table 1: Meanresult of Methane (CH_4) μg/m^3 in the study area

Sample points	Ogoja Road Dumpsite (CH_4) (μg/m^3)	New Layout Dumpsite (CH_4) (μg/m^3)	Kpirikpiri Dumpsite (CH_4) (μg/m^3)	University Farm (CH_4) (μg/m^3)
A	7.12	19.02	11.74	0.00
B	9.00	17.75	14.09	0.00
C	15.30	14.30	18.43	0.00
D	18.02	11.00	20.00	0.00
FLSD $_{0.05}$	0.02	0.05	0.03	0.00
Standard[15]	1000.00	1000.00	1000.00	1000.00

FLSD: Fishers Least Significance Difference and WHO: World Health Organization

Table 2: Mean result of Hydrogen Sulphide (H_2S) μg/m^3 in the study area

Sample points	Ogoja Road Dumpsite (H_2S) (μg/m^3)	New Layout Dumpsite (H_2S) (μg/m^3)	Kpirikpiri Dumpsite (H_2S) (μg/m^3)	University Farm (H_2S) (μg/m^3)
A	25.02	12.00	14.02	0.00
B	30.00	12.10	13.13	0.00
C	19.23	15.02	13.00	0.00
D	13.17	17.19	12.42	0.02
FLSD $_{0.05}$	0.01	0.02	0.03	0.00
Standard[15]	10.00	10.00	10.00	10.00

FLSD: Fishers Least Significance Difference and WHO: World Health Organization

The H_2S concentration levels in the Kpirikpiri Dumpsite varied from 12.42 to 14.02 μg/m^3 at every location that was studied. As can be seen from the table, they exceeded the established standards, while sample points A, B and C were found to have equal concentration levels of 0.00 μg/m^3 at the control.

However, sample point D recorded the highest concentration level at 0.02 μg/m^3.

The higher concentration levels of hydrogen sulphide (H_2S) observed in Kpirikpiri, Ogoja Road and New Layout dumpsites, which are above the threshold limit of 10 μg/m^3, may be caused by biological decay, gas leaks from nearby wetlands and microorganisms that break down organic waste quickly and produce hydrogen sulphides. In the absence of oxygen gas, like in wetlands and sewage, hydrogen sulphide drives the prokaryotic breaking of organic matter, a process known as anaerobic digestion[23]. In contrast, the low quantities seen in the control area may be caused by the absence of a dumpsite and biological degradation.

However, it has a pungent odour that, even at extremely low concentrations, gives off a very distinct rotten egg smell. The H_2S in the environment can cause eye, throat and lung discomfort; nausea, headaches and nasal blockages, difficulty sleeping, weight loss, chest pain and asthmatic flare-ups[24]. Because of their increased odour sensitivity, humans can detect hydrogen sulphide odours at concentrations as low as 0.5–1 μg/m^3 [18].

Carbon monoxide (CO) concentration (μg/m^3): The Ogoja road waste dumpsite sample points A, B and C recorded the highest carbon monoxide concentration levels of 20.42, 20.40 and 19.23 μg/m^3, while sample point D recorded the lowest concentration level of 15.30 μg/m^3, as shown in Table 3. They were statistically different and all above the permissible limit of 10 μg/m^3 as stipulated by the standard[15].

At sample point A at the New Layout Dumpsite, the highest CO concentration was observed to be 23.28 μg/m^3, which was higher than the concentrations observed at sample points B, C and D, which were 21.24, 21.10 and 17.29 μg/m^3, respectively.

The carbon monoxide concentration levels observed at the Kpirikpiri Dumpsite during the monitoring period ranged between 15.59 and 20.59 μg/m^3, respectively. Throughout the monitoring periods, there were significant variations in carbon monoxide concentration levels in the study area.

At the University Farm, sample point A recorded the highest concentration level of 0.32 μg/m^3, while sample points B and D had the lowest concentration levels of 0.28 μg/m^3, respectively.

The presence of parking lots next to the dumpsites may have contributed to the extremely high levels of carbon monoxide detected at Ogoja Road, New Layout and Kpirikpiri Dumpsites. However, it is also possible that some lunatic locals set the area on fire for cooking purposes. It could also be caused by combustion-related emissions from generator sets or by traffic congestion. A by-product of incomplete carbon combustion is carbon monoxide. It is typically produced at the exhaust ports of stationary engines and moving vehicles. According to Nabegu[25], carbon monoxide is frequently considered a contaminant when connected to vehicles, aeroplanes, power plants and human activities, such as the burning of fossil fuels like gasoline and natural gas.

In addition, the ozone layer is destroyed by a high atmospheric concentration of carbon dioxide, which is a by-product of methane and results in global warming. A study was conducted to evaluate the air quality at solid waste disposal sites in Nigeria that experienced fires. The CO levels were measured to be between 401 and 405 μg/m^3, respectively[26].

Table 3: Results of Carbon Monoxide (CO) μg/m^3 in the study area

Sample point	Ogoja Road Dumpsite (CO) (μg/m^3)	New layout Dumpsite (CO) (μg/m^3)	Kpirikpiri Dumpsite (CO) (μg/m^3)	University Farm (CO) (μg/m^3)
A	20.42	23.28	15.59	0.32
B	20.40	21.24	18.62	0.28
C	19.23	21.10	20.11	0.29
D	15.30	17.29	20.59	0.28
FLSD $_{0.05}$	0.03	0.02	0.05	0.04
Standard[15]	10.00	10.00	10.00	10.00

FLSD: Fishers Least Significance Difference and WHO: World Health Organization

Table 4: Mean result of Nitrogen Dioxide (NO_2) μg/m^3 in the study area

Sample point	Ogoja Road Dumpsite (NO_2) (μg/m^3)	New Layout Dumpsite (NO_2) (μg/m^3)	Kpirikpiri Dumpsite (NO_2) (μg/m^3)	University Farm (NO_2) (μg/m^3)
A	1.15	1.04	1.03	0.00
B	1.03	1.20	1.03	0.00
C	1.03	1.15	1.03	0.02
D	1.03	1.09	1.03	0.00
FLSD $_{0.05}$	0.01	0.01	0.02	0.01
Standard[15]	0.06	0.06	0.06	0.06

FLSD: Fishers Least Significance Difference and WHO: World Health Organization

Table 5: Mean result of particulate matter ($PM_{2.5}$) μg/m^3 in the study area

Sample point	Ogoja Road Dumpsite ($PM_{2.5}$) (μg/m^3)	New Layout Dumpsite ($PM_{2.5}$) (μg/m^3)	Kpirikpiri Dumpsite ($PM_{2.5}$) (μg/m^3)	University Farm ($PM_{2.5}$) (μg/m^3)
Point of source	245.30	314.77	202.12	2.01
(50 m) downwind	320.33	470.66	301.44	2.22
FLSD$_{0.05}$	2.33	2.12	2.23	0.46
Standard[15]	45.00	45.00	45.00	45.00

FLSD: Fishers Least Significance Difference and WHO: World Health Organization

Nitrogen dioxide (NO_2) gas concentration (μg/m^3): According to Table 4, the NO_2 concentration level at the Ogoja Road Dumpsite throughout the monitoring period was observed to be highest at sample point A with 1.15 μg/m^3 and was lowest at sample points B, C and D with 1.03 μg/m^3.

At the New Layout Dumpsite, sample point B recorded the highest concentration level of 1.20 μg/m^3, while sample point A had the lowest concentration level of 1.04 μg/m^3.

At the Kpirikpiri Dumpsite, NO_2 concentration levels were consistently observed to be 1.03 μg/m^3 at all sample sites.

Sample points A, B and D showed uniform concentration levels of 0.00 μg/m^3 at the University Farm, but sample point C showed a small difference of 0.02 μg/m^3.

All the locations studied were statistically different. The University Farm fell within the threshold limit, while other locations were all above the 0.06 μg/m^3 threshold limits[15].

The incomplete combustion of fossil fuels or oil mills may be the cause of the increased nitrogen dioxide concentration levels detected in the Ogoja Road, New Layout and Kpirikpiri Dumpsites, which exceeded the threshold limits. This was in line with Iorhemen *et al.*[27] assertion that human activity is the main source of nitrogen dioxide, which is a combination of combustible materials including coal, gas and oil, as well as the premium motor spirit used in automobiles. Nitrogen dioxide can lower immunity to lung infections by inflaming the lining of the lungs. However, this could result in problems including coughing, sneezing, the flu, colds and bronchitis. Humans with asthmatic tendencies may experience more frequent and profound trauma as a result of elevated nitrogen dioxide levels[27].

Particulate matter ($PM_{2.5}$) concentration (μg/m^3): The mean results of the particulate matter are shown in Table 5.

In Ogoja Road Dumpsite, New Layout Dumpsite, Kpirikpiri Dumpsite and University Farm, $PM_{2.5}$ at point of source ranged between 2.01 and 314.77 μg/m^3, while $PM_{2.5}$ at 50 m downwind recorded higher 470.66 μg/m^3 $PM_{2.5}$ in New Layout Dumpsite than 320.33, 301.44 and 2.22 μg/m^3 in Ogoja Road Dumpsite, Kpirikpiri Dumpsite and University Farm. They are statistically different and above the 45 μg/m^3 [15] recommended standard. The study was conducted in Yenagoa, Nigeria, where various fractions of PM, such as $PM_{1.0}$, $PM_{2.5}$, $PM_{4.0}$, $PM_{7.0}$ and PM_{10}, were recorded at solid waste management locations and their concentrations ranged from 14 to 289 μg/m^3, is comparable to the obtained mean levels of $PM_{2.5}$ during the sampling period, which was 2.01-470.66 μg/m^3. Their levels detected were less than what the current findings indicate. Additionally, it was noted that the $PM_{2.5}$ concentration dropped 50 m downstream from the source. When the source and downwind were compared, the downwind $PM_{2.5}$ concentrations were 30% higher.

Other researchers at municipal solid waste management locations have also reported similar investigations[28-30]. When air pollutants were measured in air samples from two dumping sites in Chennai, India, higher $PM_{2.5}$ levels 36 and 45 μg/m^3 were found at both sites compared to the background site's 45 μg/m^3 [30]. An earlier Chennai dumping site's particle emissions were examined in a related study. The $PM_{2.5}$ concentrations were measured in the following three seasons (summer, monsoon and winter) at an average concentration of 46, 53 and 72 μg/m^3 respectively, at a location of 0.6 km from the dump site. These measured values were below the current research results[31]. However, the high concentration observed in the current study raises the concern that inhalation of $PM_{2.5}$ from the waste dump sites may lead to respiratory diseases, cardiovascular diseases, gastrointestinal diseases, allergic diseases, musculo-skeletal diseases and other health problems in workers and the population living near the dump sites. Fine particles in liquid droplets penetrate deeper into the lung and cause severe health problems by interfering with many biological processes[32,33].

Meteorological parameters of the study area: In Table 6, meteorological parameters (temperature, humidity and wind speed) at Ogoja Road Dumpsite, New Layout Dumpsite, Kpirikpiri Dumpsite and University Farm were 30-39°C, 26-49% and 0.23-2.61 m/s, respectively.

Regression and correlation statistics between $PM_{2.5,}$ meteorological parameters and greenhouse gases in the study area: The association between $PM_{2.5}$ and greenhouse gases (CO, NO_2 and H_2S) as well as meteorological indicators was observed at all sampling sites using regression analysis (Table 7). Greenhouse gases and climatic conditions are independent variables, whereas the level of $PM_{2.5}$ is a dependent variable. Changes in dependent variables correlate with changes in independent variables, according to the significant model. While the negative link between pollutants demonstrated their inverse association, the strong positive association demonstrated their direct relationship since they were each other's source of emissions.

Table 6: Mean result of meteorological parameters in the study area

Meteorological parameter	Ogoja Road Dumpsite	New Layout Dumpsite	Kpirikpiri Dumpsite	University Farm
Temperature (°C)	39.00	36.00	32.00	30.00
Humidity (%)	49.00	42.00	36.00	26.00
Wind speed (m/s)	2.46	2.61	1.99	0.23

Table 7: Regression and correlation statistics tabulation

Correlation statistics	Ogoja Road Dumpsite	New Layout Dumpsite	Kpirikpiri Dumpsite	University Farm
Correlation coefficient	0.821	0.844	0.868	0.534
r^2	0.621	0.714	0.783	0.322
Coefficient of Determination (%)	62.000*	71.000*	78.000*	32.000

*Indicates significant level

Table 7 showed a significant negative relationship between CO, NO_2, H_2S and $PM_{2.5}$ at University Farm and a significant positive relationship between these parameters at Ogoja Road, New Layout and Kpirikpiri Dumpsite locations. Furthermore, at the same three sites, CO, NO_2 and H_2S all contributed to one another's emissions.

The Ogoja Road Dumpsite demonstrated a positive correlation coefficient (r) = 0.821 and r = 0.621 at p = 0.05 between CO, NO_2, H_2S and $PM_{2.5}$. The CO, NO_2, H_2S and $PM_{2.5}$ were shown to be positively correlated at the New Layout Dumpsite, with correlation coefficients (r) = 0.844 and 0.714 at p = 0.05. Additionally, Kpirikpiri Dumpsite demonstrated a positive association (correlation coefficient (r) = 0.868 and r = 0.783 at p = 0.05) between CO, NO_2, H_2S and $PM_{2.5}$. On the other hand, University Farm showed a negative association (r = 0.534 and r = 0.322 at p = 0.05) between CO, NO_2, H_2S and $PM_{2.5}$. At every sampling location, the connection between temperature, wind and humidity was likewise inverse.

Table 7 shows the model summary for all sampling sites. It shows that Ogoja Road, New Layout and Kpirikpiri Dumpsite were statistically significant and explained 62, 71 and 78% of the changes, respectively. University Farm was statistically not significant and accounted for 32% of the changes, respectively.

A positive correlation between CO, NO_2, H_2S and CH_4 was found in this study (Table 7), which was consistent with the results of other research[34,35]. China was asked to compare the gas emissions from the Wuhan City disposal site; current study results and theirs were similar. At two distinct locations, a significant correlation was found between CO, NO_2, H_2S and CH_4[36]. The examination of the correlation between $PM_{2.5}$ and greenhouse gases at waste dump sites has not received much attention. The correlation matrix in our analysis showed a significant relationship between greenhouse gases and $PM_{2.5}$.

Measurements of PM, CO and NH_3 levels in open cowsheds were made in Estonia, in Northern Europe. Manure and feed were the primary drivers of organic material and the main contributors to the release of greenhouse gases and there was a significant positive correlation found between PM and CO[37]. Pollutant releases at the waste dump site were also caused by vehicle exhaust and combustion activities. Another study that evaluated the levels of PM and CO on train platforms and within automobiles was carried out in Korea. The results showed a correlation matrix between the two pollutants[38].

The current study found a positive correlation between meteorological parameters and CH_4, H_2S, NO_2 and CO. Depending on the waste's depth, measurements of humidity and gas emissions must be made for both aerobic and anaerobic conditions. Increased moisture led to a decrease in oxygen concentrations and an expansion of the CH_4 outflow, as shown by Barlaz *et al.*[39]. Humidity and temperature were also shown to be negatively correlated and humidity may have been influenced by temperature. These effects were consistent with studies conducted by Barlaz *et al.*[39]. There are numerous research studies that monitor how meteorological factors affect the fate of harmful chemicals in the surrounding air[22,40]. According to the current evaluations, rising temperatures and calmer wind speeds cause PM to become more mobile due to dusty air, which raises PM levels and was consistent with previous research[40]. According to our observations, the different management procedures used by waste dumpsites have a considerable effect on the ambient air quality.

CONCLUSION

The study's findings revealed that while CH_4 is within the recommended level, CO, NO_2, H_2S, and $PM_{2.5}$ concentration levels in the atmosphere were observed to have exceeded WHO regulation guidelines. Rather than near the source, a rise in $PM_{2.5}$ concentrations was detected (50 m) downwind. The amount of greenhouse gases and $PM_{2.5}$ in the atmosphere was also influenced by meteorological conditions. In Ebonyi State, the Ogoja Road, New Layout and Kpirikpiri areas are highly populated. Therefore, there should be a need to continuously monitor the air quality in Ebonyi State, Nigeria, particularly around solid waste dumps, to prevent dangerous air pollution and ensure the safety of the locals.

SIGNIFICANCE STATEMENT

The purpose of the study was to determine the environmental impact of solid waste generation on air quality in Ebonyi State, Nigeria. The set objectives were to examine the methane gas, hydrogen sulphide gas, carbon monoxide gas, nitrogen dioxide gas, particulate matter concentration and meteorological parameters of the study area. The study's findings revealed that while CH_4 is within the recommended guidelines, CO, NO_2, H_2S, and $PM_{2.5}$ concentration levels in the atmosphere were found to have exceeded WHO guidelines. The level of $PM_{2.5}$ increased downwind instead of at the source site. The amount of greenhouse gases and $PM_{2.5}$ in the atmosphere was also influenced by the weather. The study will be of great benefit to all, to ensure environmental consciousness.

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