Ammonia Emission Levels at Dumpsites and its Fluctuation with Some Atmospheric Properties

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Abstract
This study assessed ammonia (NH_3) emissions levels at dumpsites and its fluctuation with measured atmospheric properties at selected dumpsites. The study was conducted at three dumpsites—Egbelu, Obiri-Ikwerre, and Iwofe in Obio Akpor Local Government Area of Rivers State, using a geographical positioning system (GPS), ammonia detector, anemometer, digital thermometer, digital hygrometer and measuring tape to obtain the data at the selected dumpsites on a daily basis for a period of two weeks. The results obtained indicated that NH_3 concentration varied across the dumpsites. Obiri-Ikwerre recorded the highest average NH_3 concentration of 1.014 ppm, Egbelu had 0.99 ppm, and Iwofe had the lowest concentration value of 0.88 ppm. A positive correlation was found between NH_3 concentration and temperature, while relative humidity and wind showed negative correlations. NH_3 levels of the selected dumpsites during the study period were far below the Occupational Safety and Health Administration permissible exposure limit (PEL) of 50ppm and the National Institute for Occupational Safety and Health Administration recommended exposure limit (REL) of 25ppm. This study establishes the interplay between atmospheric properties and NH_3 emissions and accentuates the need to consider these factors in waste management practices and NH_3 emission mitigation strategies to curtail the effects of ammonia gas has on local air quality, human health and the environment at large.

Keywords: Ammonia Emission, Dumpsite, Fluctuation, Atmospheric Properties

1. Introduction

The improper waste disposal and management, especially in low income countries around the globe poses serious environmental problems. The level of waste generation in many urban areas is attributed to large population of people and the volume economic activities. Emissions from waste have risen by an average of 2% each year since 2005, to represent 3% of total ammonia emissions in 2021(Chandna et al., 2013). According to the World Bank, 2.01 billion tons of Municipal solid waste (MSW) was generated in 2016, and up to 3.40 billion tons will be generated by 2050 under a business-as-usual scenario (Kaza et al., 2018). Studies have shown that the state agencies responsible for waste management do not have adequate trucks/vehicles and equipment for waste transportation and the ones available are poorly maintained or are non-functional (Ibikunle et al., 2021). MSW generation is expected to increase in developing countries such as Nigeria, where income level and population (both influencing consumption pattern) are rising steadily (Nasralla, 1985). Open dumpsites scattered in the urban centers produce offensive odour and contaminates the environment Anaerobic reactions within the dumpsites generate leachate and contaminate the soil, water, and well as the air we breathe. Air pollution has negative impacts on human health and the environment (Cogut, 2016). The act of burning open solid wastes poses serious environmental problems as it results in the emissions of SO_2, NO_x and NH_3 which have potential adverse health effect on those residing within the vicinity of the solid wastes (Ipeaiyeda & Falusi, 2018). In 2022, 3 per cent of total ammonia emissions came from waste (Department for Food and Rural Affairs, 2024 February 24). "Ammonia (NH_3) contributes to widespread adverse health impacts, affects the climate forcing of ambient aerosols, and is a significant component of reactive nitrogen, deposition of which threatens many sensitive ecosystems" (Zhu et al., 2015). "Long-term exposure of ammonia did not cause a specific carcinogenic disease, but in some cases can cause a permanent burn injury, unusual habit in breath, and in special case can cause a brain related disease" (Diana et al., 2018). High concentrations of gaseous ammonia (NH_3) are toxic to most plant species, leading to harmful physiological effects, such as visible damage to foliage (Nordin et al., 2011). The European Union (EU) has set 8 µg/m³ as the critical threshold above which NH_3 concentrations can directly harm plants, although some researchers believe this limit may be too high (Cape et al., 2009). Emission rates or surface emission fluxes are often necessary to determine environmental impacts and human health risks, as well as to monitor the results of pollution control activities (Canzano et al., 2010).

1.1 Ammonia and its sources

Ammonia gas comes from both natural and anthropogenic origins. "The primary sources of NH_3 emissions from agriculture include livestock and animal production, manure handling and storage, livestock housing and the application of manure/slurry and artificial fertilizers to land and these contribute to more than 81% of all global ammonia emissions" (Wyer etal., 2022). Non-agricultural sources of NH_3 include the production of nitrogen fertilizers, coal and biomass burning, waste incineration, wastewater treatment, landfills, and emissions from animals such as horses, pet dogs, cats, wild animals, and seabirds (Sutton et al., 2000). Transport-related emissions arise from vehicles equipped with three-way catalytic converters, which are designed to reduce nitrogen oxides (NOx) but release NH_3 as a by-product (Cape et al., 2004). According to Doyle et al. (2014) in Ireland, for instance, NH_3 levels are strongly correlated with cattle populations, which account for at least 75% of total emissions.

1.2 Ammonia gas and Climate Change

The spatial distribution of ammonia in the atmosphere is closely linked to its sources.

According to The Royal Society (2020) "ammonia itself is not a greenhouse gas, but following deposition to soil it may be converted to nitrous oxide, an important contributor to radiative forcing of climate and also possesses a substantial indirect impact on climate through its role in particulate matter". Rathod et al. (2023) reported that ammonia emissions contribute to local air pollution via the formation of secondary particulate matter.

Rising levels of gases in the Earth's atmosphere have the potential to cause changes in our climate, and Some of these emission increases can be traced directly to solid waste (USEPA, 2002). These particles can contribute to the formation of fine particulate matter ($PM_{2.5}$), which is associated with respiratory and cardiovascular diseases (Erisman et al., 2007). The manufacture, distribution, and use of products-as well as management of the resulting waste-all result in greenhouse gas emissions (Karki, 2015).

1.3 Atmospheric Properties (temperature and relative humidity) and Ammonia

The conversion of gaseous ammonia to particle ammonium, particularly in autumn have been found to be favoured by lower temperature and higher humidity conditions (Wang et al., 2015). A study on "Fine Particle pH and Sensitivity to NH_3 and HNO_3 over South Korea During KORUS-AQ" by Ibikunle et al.(2024) showed that variations in temperature have a significant impact on NH_3 concentrations. Temperature plays a crucial role in the volatilization of ammonia in agricultural setting. The finding of a research study by Fan and Kumar (2011) showed that an increase in temperature from 20 to 30 °C increased cumulative NH3 volatilization loss in the sandy soil by 1.4-, 1.7. This relationship is particularly evident during warmer seasons when agricultural activities, such as manure spreading, coincide with elevated temperatures, resulting in peak ammonia emissions (Sutton et al., 2013). The increase in temperature enhances the kinetic energy of ammonia molecules, reducing its solubility in water and causing more ammonia to enter the atmosphere as a gas (Sommer & Hutchings, 2001).

Relative humidity also exerts a significant influence on ammonia dynamics. In conditions of high relative humidity, ammonia tends to interact with water vapor in the air, leading to the formation of ammonium aerosols, such as ammonium nitrate or ammonium sulfate, through reactions with acidic gases like sulfur dioxide (SO_2) and nitrogen oxides (NO_x) (Seinfeld & Pandis, 2016). These aerosols contribute to fine particulate matter ($PM_{2.5}$) in the atmosphere, which has implications for air quality and human health. Conversely, under low humidity conditions, ammonia is less likely to form aerosols and remains in its gaseous state, which can lead to increased atmospheric concentrations and longer-range transport of ammonia (Clarisse et al., 2019).

The interplay between temperature and relative humidity also affects the deposition of ammonia. Higher temperatures combined with low humidity conditions can result in decreased ammonia deposition rates, as ammonia remains in the gas phase and is less likely to deposit onto surfaces such as soil or vegetation (Flechard et al., 2011). Lower temperatures and higher humidity levels can speed up the deposition of ammonia through wet and dry deposition processes, impacting ecosystem in terms of soil acidification and nutrient enrichment. In a severe atmospheric condition, such as heatwaves or periods of drought, can increase the levels of ammonia emissions and alter its chemistry in the atmosphere. For instance, during heatwaves, elevated temperatures can accelerate ammonia volatilization, while low humidity may reduce aerosol formation, thereby increasing the atmospheric burden of ammonia (Van Damme et al., 2018). Such conditions pose challenges for air quality management, particularly in regions with intensive agricultural activities.

1.4 Ammonia Estimates from Previous studies

Kumar et al. (2019) in their study, noted that "ambient Ammonia (NH_3) concentration level is always under prescribed limit of government regulatory authorities but the concentration level tends to be higher in surrounding regions of a chemical fertilizer industry". In their study, the spatial average concentration of NH_3 in Mumbai city were found to be to be 85 $\mu g/m^3$ and 56 μg/m^3. The lowest measured mean level in a conducted by Nnadozie et al. (2020) in Owerri Metropolis was 0.04633 mg/L and this value said to have exceeded the critical loads and occupation exposure limits. Phan et al. (2013) did long-term monitoring of ammonia concentration and other trace gases at hourly intervals along with meteorological parameters in Seoul, Korea for a one-year period (1 September 2010–23 August 2011). The mean ammonia concentrations measured at two sites (Gwang-Jin (GJ) and Gang-Seo (GS) districts) were 10.9 ± 4.25 and 12.3 ± 4.23 ppb, respectively. Ngele et al (2017) conducted a study on the ambient air ammonia concentration into two solid waste dump sites in Abakaliki and the the result showed that side 1 had a relatively higher mean ammonia level of 0.152±0.03ppm as against 0.09±0.02ppm for site

2. Materials and Method

2.1 Study Area

Obio/Akpor Local Government Area is one of the major centers of economic activities in Rivers State and located at 4°49' 53.0" N, 6°59' 20.6" E, with an elevation of 24 meters above sea level, and an area of 230 Km^2. The 2006 national population census figure of Obio/Akpo was 464,789 and a population projection of 665,000 in 2022. Its geology comprises basically of alluvial sedimentary basin and basement complex. The region falls within the Mangrove forest zone and has an average humidity of 73% and the average temperature of 25^{o}C. Obio/Akpor LGA witnesses two seasons which are the dry and the rainy seasons with the rainy seasons in the area usually characterized by heavy and frequent showers. Trade is also a critical aspect of the economy of Obio/Akpor, with the area hosting a number of markets, industries, financial institutions, schools, hotels, restaurants, relaxation spots and government-owned institutions which all contribute to the economy of the LGA.

2.2 Materials
The following materials were implored in this study. These include geographical positioning system (GPS), ammonia detector, wind vane and measuring tape.

2.3 Method
The geographical locations of the selected dumpsites-Egbelu, Obiri-Ikwerre, and Iwofe dumpsites were determined using GPS, relative humidity (RH), and the temperature of these selected dumpsites were recorded during the period under study. The ammonia monitor was positioned 1 meter away and 1.5 meter above the ground with the help of a measuring tape to determine the ammonia emission concentration levels of the respective dumpsites. These procedures were carried out on a daily basis for a period of two weeks.

2.4 Data Analysis
The data obtained were analyzed using statistical tools such as bar chat, scatter plots and graphs.

3. Results and Discussion

Table 1 is the geographical coordinates of the selected dumpsites

Table 1: Geographical Coordinates of the selected Dumpsites

S/N	Location	Geographical Coordinates
1.	Obiri Ikwerre Dumpsite	N4^{o} 90' 6.07", E6^{o} 96' 2.68"
2.	Egbelu Dumpsite	N4^{o} 50' 5.57" E6^{0} 57" 0.27"
3.	Iwofe Dumpsite	N4^{o} 48' 3.06" E 6^{0} 55' 5.85"

Figure 1 is the ammonia concentration levels of the selected dumpsites

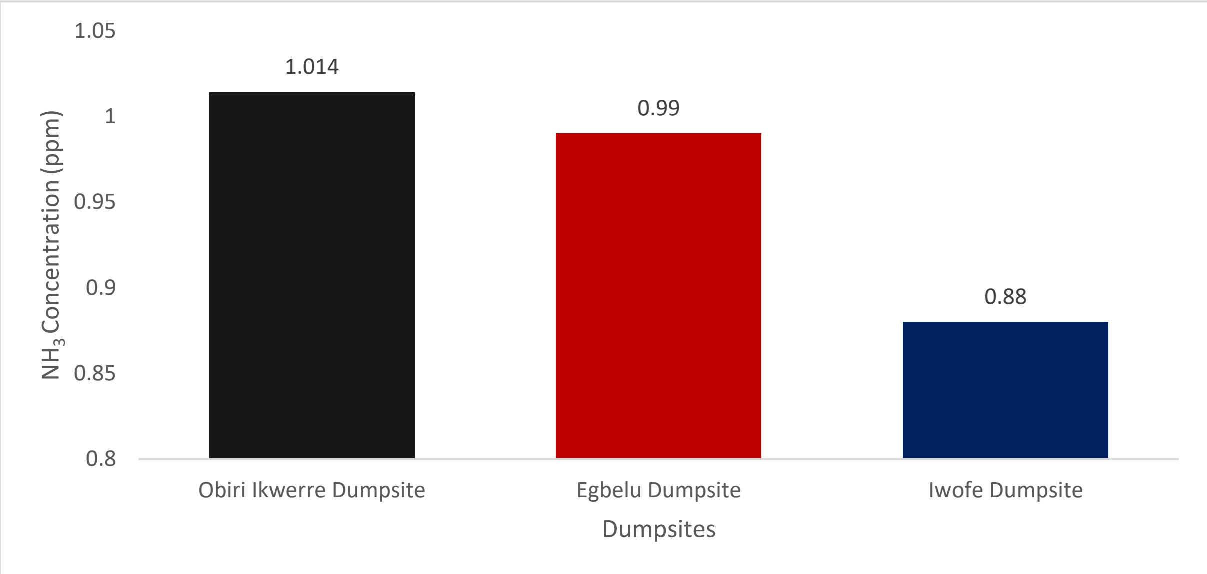

Figure 1: **Ammonia (NH_3) Emission Concentrations Levels of the Selected Dumpsites.**

Ammonia (NH_3) emission concentrations at the Obiri Ikwerre, Egbelu, and Iwofe dumpsites were monitored for 14 days. Obiri Ikwerre recorded the highest average NH_3 concentration level of 1.014 ppm, possibly due to more organic waste and environmental factors such as and relative humidity, temperature and wind speed. Egbelu had a slightly lower average of 0.99 ppm, while Iwofe showed the lowest concentration levels of 0.88 ppm. These results highlight variations in ammonia emissions across the dumpsites, reflecting site-specific factors.

Ammonia (NH_3) emissions have significant environmental and health impacts, particularly when released in high concentrations from sources like dumpsites. Environmentally, elevated NH_3 levels can contribute to the formation of fine particulate matter ($PM_{2.5}$) and secondary pollutants like ammonium nitrate and ammonium sulfate, which can exacerbate air pollution. These pollutants can travel long distances, affecting air quality far from the original emission source. NH_3 is crucial in soil and water acidification, which can harm ecosystems by altering nutrient balances, leading to reduced biodiversity and the disruption of natural habitats.

Health-wise, prolonged exposure to ammonia emissions can irritate the respiratory system, eyes, and skin. In high concentrations, NH_3 can exacerbate respiratory conditions such as asthma and bronchitis, posing significant risks to vulnerable populations, including children, the elderly, and individuals with pre-existing health conditions. Chronic exposure, even at lower levels, may lead to long-term health effects, including respiratory dysfunction and other systemic issues. The impact of NH_3 emissions, therefore, necessitates stringent regulatory measures and effective waste management practices to protect both environmental and public health.

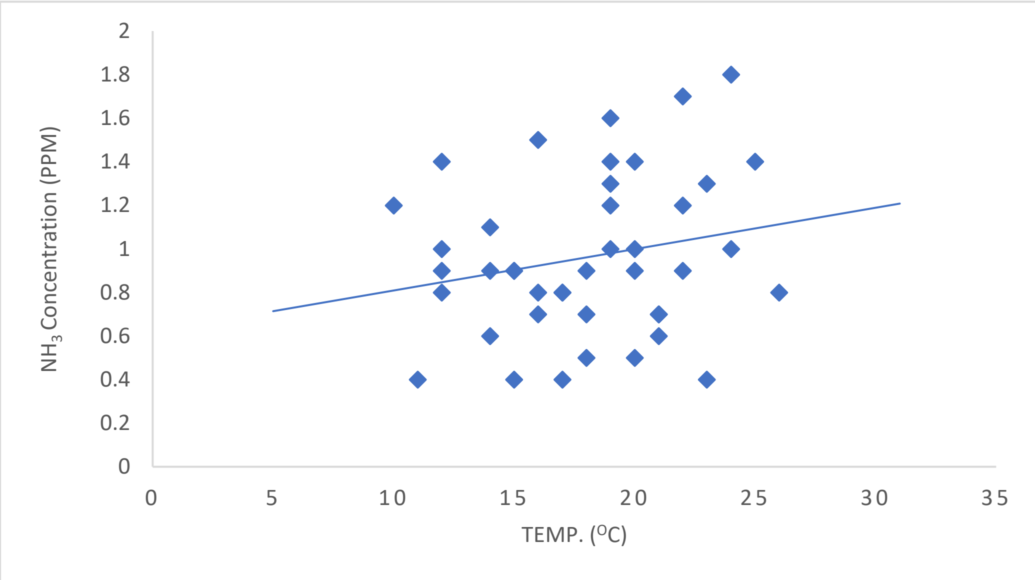

Figure 2: Scatter plot showing correlation between NH_3 concentration levels and Temperature

The scatter plot in fig 4.2 shows a positive correlation between ammonia (NH_3) concentration level and temperature, as indicated by the upward-sloping trend line. This shows that as temperature increases, NH_3 concentration tend to rise. However, the relationship appears to be weak, as the data points are scattered around the trend line, indicating variability in ammonia levels at similar temperatures. This variability shows that while temperature influences NH_3 concentrations, other factors like, relative humidity and wind speed may also be at play. The analysis suggests that these atmospheric conditions might interact with the chemical and physical processes affecting NH_3 emissions. Higher temperatures, as observed at Iwofe Dumpsite, are generally associated with increased volatilization of ammonia from decomposing organic matter, leading to higher NH_3 concentrations. However, this relationship can be modulated by relative humidity, which influences the moisture content in the air and the chemical reactions involving ammonia. For instance, at Iwofe, despite the higher temperature, the NH_3 concentration was slightly lower than at Obiri Ikwerre, which could be attributed to the high relative humidity (80.31%), possibly leading to more ammonia being absorbed into the moisture-laden atmosphere, reducing its concentration in the air.

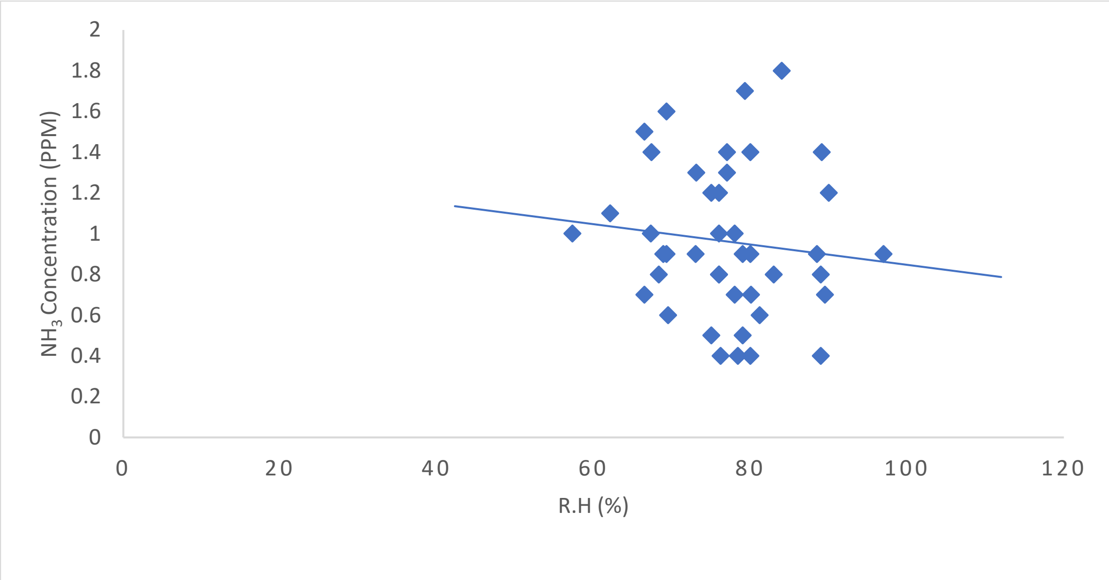

Figure 3: Scatter plot showing correlation between NH_3 concentration levels and Relative Humidity

In figure 4.3, the scatter plot shows a negative correlation between ammonia (NH_3) level and relative humidity, as indicated by the downward-sloping trend line. This shows that as relative humidity increases, NH_3 concentrations tend to decrease. The scattered data points around the trend line indicates variability in ammonia levels at different humidity levels. This variability shows that while relative humidity appears to influence NH_3 concentrations, other factors may also contribute to the observed spread of data points. The correlation between NH_3 (ammonia) concentrations and relative humidity reveal that higher humidity levels reduce ammonia concentration in the air by increasing moisture absorption.

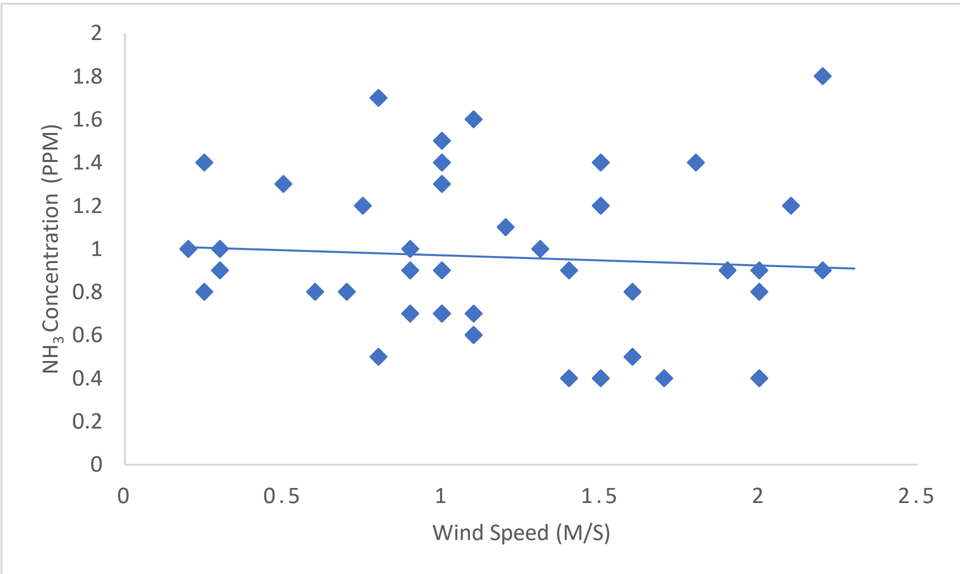

Figure 4: Scatter plot showing correlation between NH_3 concentration levels and Wind Speed

The scatter plot in fig 4.4 shows a weak negative correlation between ammonia (NH_3) levels and wind speed, indicated by the slight downward slope of the trend line. This shows that as wind speed increases, ammonia concentrations may slightly decrease, although the relationship is not strong. The considerable variability in data points around the trend line implies that wind speed has a minimal impact on NH_3 levels, and other factors may be influencing ammonia concentrations. Wind speed is critical to the dispersion of NH_3 emissions. At Obiri Ikwerre, the higher average wind speed of 1.35 m/s could facilitate the dilution and dispersion of ammonia, potentially lowering its localized concentration despite a relatively moderate temperature. In contrast, the lower wind speeds at Egbelu and Iwofe might result in less dispersion, allowing ammonia concentrations to build up more in these areas. These findings highlight the complex interplay between temperature, relative humidity, and wind speed in determining the concentration of ammonia emissions, and suggest that effective management of NH_3 emissions requires a nuanced understanding of local atmospheric conditions.

3.1 Atmospheric Properties (temperature, relative humidity and wind) of the Selected Dumpsites

The atmospheric properties (temperature, relative humidity and wind speed) at the selected dumpsites—Obiri Ikwerre, Egbelu, and Iwofe are shown in figures 5, 6 and 7.

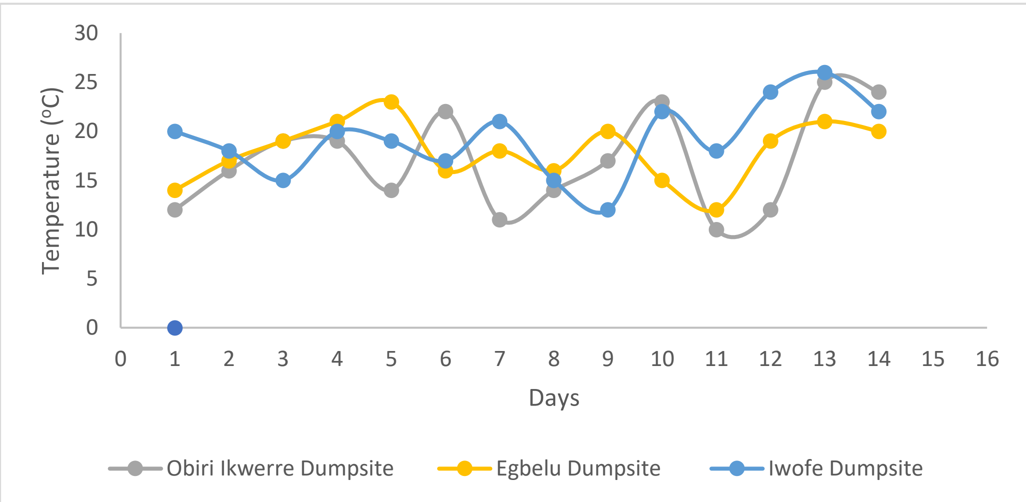

Figure 5: Temperature Curves for the Selected Dumpsites

Figure 5 shows a daily variation of temperature at the selected dumpsites with Iwofe dumpsite having the highest average temperature of 19.21°C followed by Egbelu and Obiri Ikwerre dumpsites with average temperatures of 17.93°C and 17°C respectively. The change in temperature could be attributed to change in other atmospheric variables (like relative humidity and wind speed) and some physical activities like the burning of wastes.

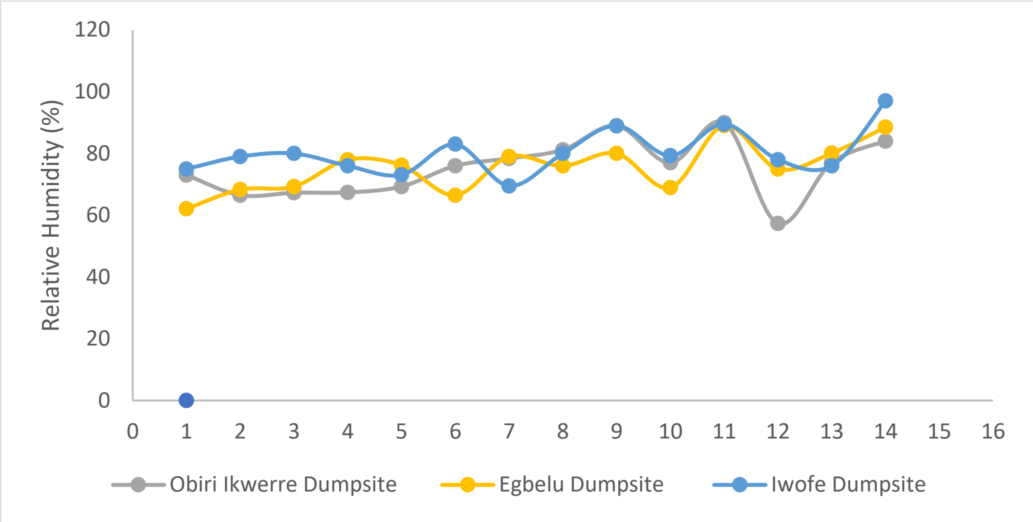

Figure 6: Relative Humidity (%) Curves for the Selected Dumpsites

The daily relative humidity of the selected dumpsites varied slightly during the period under study with Iwofe dumpsites having the highest relative humidity of 80.31% followed by Egbelu with average relative humidity of 75.5% while Obiri Ikwerre dumpsite had an average relative humidity of 75.24%. The difference in relative humidity could be attributed to change in other atmospheric variables and the nature of the respective dumpsite terrains.

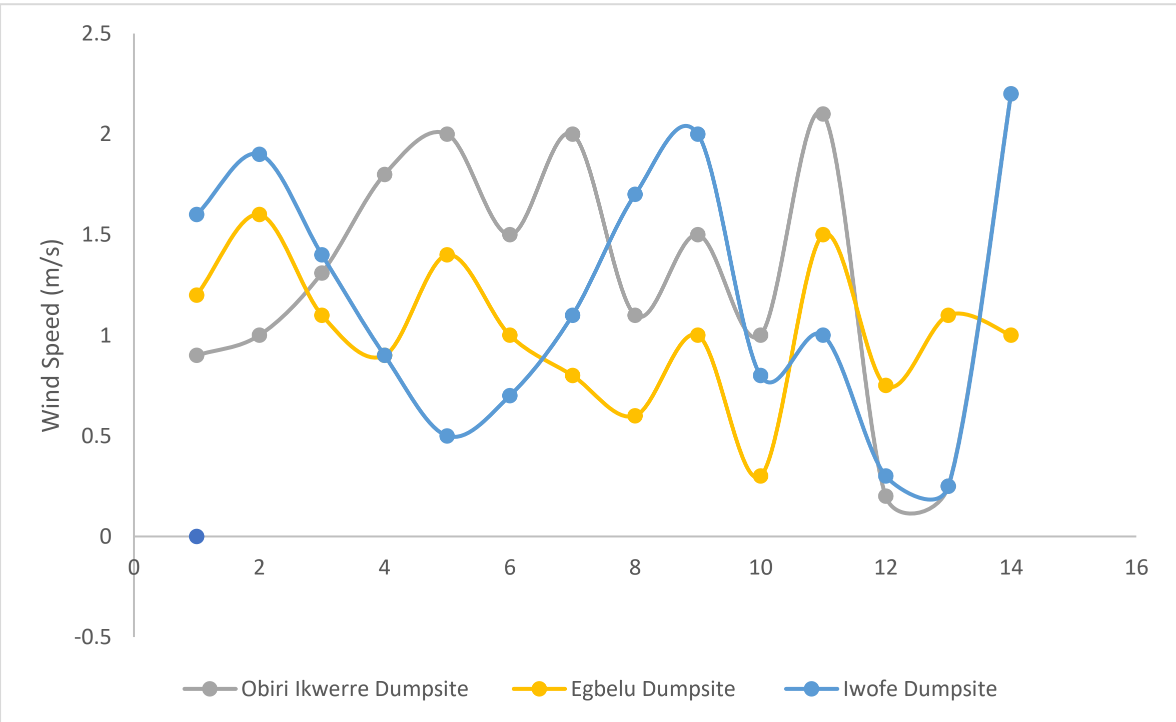

Figure 7: Wind Speed (m/s) Curves for the Selected Dumpsites

Figure 7 shows the daily variation of wind Speed at the different locations(dumpsites) with Obiri Ikwerre dumpsite having the highest average wind speed of 1.35 m/s followed by Iwofe and Egbelu dumpsites with average wind speeds of 1.17 m/s and 1.02 m/s respectively. The change in wind speed could be attributed to a change in other atmospheric variables and the topography of the respective dumpsites.

3.2 Comparison of NH_3 Emission Concentration Levels with Set Standards and Implication of Results

The NH_3 emission concentration levels at the three dumpsites (Obiri Ikwerre, Egbelu, and Iwofe) fluctuate over the 14-day period, with mean concentrations of 1.014 ppm, 0.99 ppm, and 0.88 ppm, respectively. NH_3 levels of the selected dumpsites during the study period were far below the Occupational Safety and Health Administration permissible exposure limit (PEL) of 50ppm and the National Institute for Occupational Safety and Health Administration recommended exposure limit (REL) of 25ppm. This implies that ammonia levels emitted from the selected dumpsites for the period under have no serious human health and environmental problems.

3.3 Conclusion

This study establishes the interplay between atmospheric properties and NH_3 emissions and accentuates the need to consider these factors in waste management practices and NH_3 emission mitigation strategies to curtail the effects of ammonia gas has on local air quality, human health and the environment at large.

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