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INVESTIGATION OF SPECIFIC INORGANIC CONTAMINANTS AND PARTICULATE MATTER IN THE ATMOSPHERIC ENVIRONMENT OF SELECTED LOCAL GOVERNMENT AREAS IN DELTA STATE, NIGERIA

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ABSTRACT

This study evaluates selected inorganic contaminants and particulate matter in the atmosphere of specific Local Government Areas in Delta State, Nigeria, namely Warri, Uvwie, Udu, Okpe, and Ughelli. The contaminants examined include lead, ammonia, carbon monoxide, and particulate matter with diameters of 2.5 and 10 micrometers. Air samples were collected over a twelve-month period and analyzed for the presence of these substances. The results, presented as mean values from triplicate samples, indicated a consistent lead concentration of 0.001 µg/m^3 across all months and local governments. Ammonia levels varied, ranging from 0.0080 to 0.070 µg/m^3, with specific monthly concentrations of 0.012 to 0.015 µg/m^3, 0.022 to 0.052 µg/m^3, and 0.058 to 0.088 µg/m^3. Particulate matter (PM2.5) concentrations ranged from 0.141 to 0.639 µg/m^3 and 0.438 to 0.612 µg/m^3, while PM10 levels ranged from 0.202 to 0.987 µg/m^3 and 0.763 to 0.991 µg/m^3 across the months and local governments studied. The analysis of geo-accumulation and anthropogenic factors revealed that atmospheric contamination in these areas is primarily due to human activities.

Keywords: Environment, Pollution, Contaminants, Local Government, Months and Investigation.

I. INTRODUCTION

Pollution is defined as the presence of one or more harmful contaminants (pollutants) in significant amounts and for prolonged periods, which can adversely affect human health, as well as plant and animal life, or damage property. It can also unreasonably disrupt the enjoyment of life, property, or business activities (Canter, 2020). The atmospheric environment consists of the layer of gases surrounding the Earth, acting as a barrier between the planet's surface and the vastness of space (Bhatia, 2019). Concerns about air quality have likely existed since the beginning of humanity, with air pollution becoming a notable issue following the discovery of fire (Brimblecombe, 2020). Gaseous pollutants have been identified in various industrial settings, including refineries, ports, and areas adjacent to busy roads, as well as in urban environments overall (Onwukeme and Etienajirhevwe, 2020). The concentration of specific contaminants serves as an indicator of atmospheric pollution levels (Khandekar et al., 2022). A review of environmental pollution across different countries reveals a rapid increase in certain regions, while others are seeing a decline. For instance, Northern Ireland has reported elevated levels of sulfur dioxide, raising concerns that this may be linked to sulfur emissions from a lagoon near a monitoring station (Burton and Robert, 2020; Harrop, 2016). Air pollutants can originate from various anthropogenic sources, which include point or stationary sources, area sources, and mobile (linear) sources. Each source type has distinct emission characteristics. Point sources are defined locations, such as industrial facilities, while mobile sources include vehicles, aircraft, and similar entities. Emissions from these sources can be classified as controlled, uncontrolled, accidental, intentional, or fugitive (Harrop, 2022). This study aims to identify various pollutants and particulate matter in air samples collected from selected locations in the Effurun, Warri, Udu, Ughelli, and Okpe local government areas. The objectives include measuring the concentrations of lead, carbon monoxide, ammonia, as well as $PM_{2.5}$ and PM_{10} in the atmosphere of these areas in Delta State, Nigeria.

II. METHODOLOGY

Heavy Metals Sampling

Heavy metal samples were collected using a particulate matter sampler equipped with a glass fiber filter paper, which was stationed at the sampling site for fourteen days (Etienajirhevwe, 2006).

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Carbon Monoxide Measurement

An automated instrument was employed to measure the concentration of atmospheric carbon monoxide in the air.

Particulate Matter $PM_{2.5}$ and PM_{10}

Concentrations of $PM_{2.5}$ and PM_{10} were assessed using the Haz-Dust EPAM 5000 environmental dust monitoring device.

Harvesting of Samplers

All sample collectors were collected after a fourteen-day period. Initially open to allow air inflow, the samplers were sealed with special caps to prevent contamination and desorption. They were then placed in tightly sealed bags and stored in a refrigerator at a controlled temperature until processing. The glass fiber filters used for heavy metal collection were stored in an airtight container within black polythene bags. Care was taken to handle all samples meticulously to avoid contamination.

Instrumental Analyses

Heavy Metals

The glass fiber filter paper containing heavy metal contaminants was cut into small pieces and digested for thirty minutes in 100 mL of hydrochloric acid at a low heat of 50°C in an oven. The solid residue was extracted with 2M hydrochloric acid and evaporated nearly to dryness. It was then re-dissolved in 10 mL of concentrated hydrochloric acid, with the addition of ten drops of 1M trioxonitrate (V). The resulting solution was transferred to a 50 mL volumetric flask and brought to volume with distilled water. It was then filtered through blue ribbon filter paper (S&S 11589) into another volumetric flask for analysis of metal concentration using an Atomic Absorption Spectrophotometer (Perkin Elmer 2380). A digestion blank was also prepared in the same manner (Perkin Elmer Instrument, 2005). The digested and extracted samples were aspirated into the flame through an air stream as a fine mist. The sample entered the burner via a mixing chamber, where it combined with the fuel gas (acetylene) supplied to the burner, resulting in combustion. The radiation from the flame passed through a lens to the monochromator and then through an optical filter that allowed only the radiation specific to the metal being analyzed to reach a photo cell. The results were displayed on a monitor. Optical densities of standard solutions for various metal ions were measured at their respective wavelengths, and standard curves were created by plotting absorbance against metal concentrations (Ekeayanwu et al., 2010).

Particulate Matter and Carbon Monoxide

The concentrations of particulate matter and carbon monoxide were recorded using the automated instrument designated for this purpose.

III. RESULTS AND DISCUSSIONS

Table 1: Mean inorganic contaminants and particulate matter ($\mu g/m^3$) in the atmospheric environment as per months of investigation

Months	Pb	NH_3	CO	$PM_{2.5}$	PM_{10}
January	0.001a	0.008a	0.031ab	0.511de	0.801ef
February	0.001a	0.018ab	0.027ab	0.509de	0.934ef
March	0.001a	0.016ab	0.022ab	0.412d	0.851f
April	0.001a	0.041b	0.034b	0.448de	0.734d
May	0.001a	0.043b	0.052b	0.312cd	0.582de
June	0.001a	0.013ab	0.022ab	0.198bc	0.381cd
July	0.001a	0.041b	0.048ab	0.218bc	0.418d
August	0.001a	0.055b	0.039ab	0.185bc	0.335cd
September	0.001a	0.013b	0.028ab	0.512d	0.964ef
October	0.001a	0.044b	0.037ab	0.141bc	0.202bc
November	0.001a	0.070b	0.072b	0.632d	0.429de
December	0.001a	0.061b	0.085b	0.639de	0.987ef

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Control	**0.001a**	**0.001a**	**0.001a**	**0.002a**	**0.004a**

Table 2: Mean inorganic contaminants and particulate matter (μg/m^3) in the atmospheric environment as per Local Government Area of investigation

Local Govt	Pb	NH_3	CO	$PM_{2.5}$	PM_{10}
Warri	**0.001a**	**0.014b**	**0.088c**	**0.612b**	**0.983d**
Uvwie	**0.001a**	**0.015b**	**0.083c**	**0.609b**	**0.991d**
Udu	**0.001a**	**0.012b**	**0.065c**	**0.512b**	**0.861c**
Okpe	**0.001a**	**0.013b**	**0.058c**	**0.438b**	**0.763b**
Ughelli North	**0.001a**	**0.013b**	**0.077c**	**0.551b**	**0.847c**
Control	**0.001a**	**0.001a**	**0.001**	**0.002a**	**0.004a**

Lead was detected in the atmosphere at a concentration of 0.001 μg/m^3 across all months and local governments studied. This concentration matched that of the control site, indicating that the air is free from lead contamination, a finding supported by statistical analyses. The World Health Organization (WHO), Occupational Safety and Health Administration (OSHA), and the Department of Petroleum Resources (DPR) set the permissible lead level in air at 0.5 μg/m^3, confirming that the study locations are lead-free.

Common sources of atmospheric lead include the combustion of fossil fuels, such as gasoline and coal; industrial processes involving smelting, refining, and manufacturing; waste management practices like incineration and landfilling; and emissions from aircraft (Karl et al., 2023). Lead is a toxic metal that can severely impact human health and the environment. Health effects include neurological damage leading to irreversible brain injury, reduced IQ, learning disabilities, and behavioral issues in children; developmental delays such as low birth weight and premature births; cardiovascular diseases like high blood pressure, heart attacks, and strokes; kidney dysfunction resulting in chronic kidney disease and failure; and cancer, as classified by the International Agency for Research on Cancer (IARC) as probably carcinogenic to humans (Khandekar et al., 2021). Environmental impacts of lead include soil contamination, water pollution that threatens aquatic life and human health, and air pollution, where lead can combine with other airborne pollutants to form particulate matter that worsens respiratory issues (Harrop, 2022).

Ammonia gas was detected in the atmosphere at concentrations ranging from 0.008 to 0.070 μg/m^3 and 0.012 to 0.015 μg/m^3 for the months and local governments studied, respectively. These levels were higher than those at the control site, indicating potential contamination or pollution. Statistical analyses confirmed significant differences between the results from the study sites and the control, further suggesting atmospheric contamination.

The presence of ammonia can be linked to industrial activities that release it into the atmosphere, vehicle emissions—especially from those using catalytic converters to reduce nitrogen oxides—natural sources like volcanic eruptions and wildfires, human waste from sewage systems and wastewater treatment plants, biomass burning, and livestock farming, particularly poultry and swine (Onwukeme and Etienajirhevwe, 2020). Although the ammonia concentration is below the WHO recommended limit of 10 μg/m^3, its accumulation can have various adverse effects on human health and the environment. Health impacts include respiratory issues such as lung irritation and chronic respiratory problems; eye and skin irritation; neurological effects like headaches and confusion; gastrointestinal, cardiovascular, and reproductive problems. Environmental effects include acid rain damaging crops and ecosystems, eutrophication leading to harmful algal blooms, and particulate matter that reduces visibility and exacerbates respiratory health issues (Imonitie and Josiah, 2022).

Carbon monoxide, a colorless, odorless, and tasteless gas, was found in the atmosphere at concentrations ranging from 0.028 to 0.085 μg/m^3 and 0.058 to 0.088 μg/m^3 for the months and local governments studied, respectively. These levels exceeded those of the control site (0.001 μg/m^3), indicating environmental contamination. Statistical analyses revealed significant differences between the study sites and the control, confirming carbon monoxide pollution. Variations in local government results are attributed to vehicle density, with areas having more vehicles emitting higher levels of carbon monoxide.

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The presence of carbon monoxide is primarily due to fossil fuel combustion for energy and transportation, vehicular emissions, industrial processes, biomass burning, wildfires, agricultural activities, waste burning, and natural sources like volcanic eruptions (Harrop, 2022). Although the carbon monoxide concentrations in this study are lower than the WHO recommended limits of 100 mg/m^3 for a 15-minute average, 60 mg/m^3 for a 30-minute average, and 30 mg/m^3 for a 1-hour average, prolonged exposure can lead to significant environmental and health effects (USEPA, 2021). Environmental impacts include global warming, ground-level ozone formation, damage to vegetation, reduced crop yields, and harm to aquatic life. Health effects may include exacerbated respiratory conditions, increased risk of cardiovascular diseases, headaches, dizziness, confusion, birth defects, miscarriages, and certain cancers (Nguyen, 2021).

Particulate matter (PM), a complex mixture of tiny particles and droplets in the air, was found in the study area at concentrations of 0.202 to 0.987 µg/m^3 for PM10 and 0.141 to 0.639 µg/m^3 for PM2.5. Local government concentrations ranged from 0.763 to 0.991 µg/m^3 for PM10 and 0.438 to 0.612 µg/m^3 for PM2.5. All particulate matter levels were higher than those at the control site, indicating environmental contamination. Statistical analyses showed significant differences between the study months and the control, as well as among different local governments, suggesting varying levels of contamination. The density of activities in each local government correlates with the concentration of particulate matter in the environment.

Particulate matter has numerous detrimental effects on both the environment and human health. Environmental impacts include degraded air quality, reduced visibility, climate change, contamination of water bodies, and damage to infrastructure (Harrop, 2022).

Table 3: Correlation between the inorganic contaminants in the atmospheric environment

	Pb	NH_3	CO	PM_{10}	PM_{10}
Pb	**1**				
NH_3	**0.723**	**1**			
CO	**0.819**	**0.865**	**1**		
$PM_{2.5}$	0.628	**0.436**	**0.467**	**1**	
PM_{10}	0.652	**0.763**	**0.345**	**0.534**	**1**

Table 3 above showed results of the correlation matrix between the inorganic contaminants found present in the atmospheric environment. Observation of the correlation matrix suggests: Strong positive correlations between Pb, CO, and NH3; moderate positive correlations between Pb, $PM_{2.5,}$ and PM_{10}, strong positive correlations between NH3 and CO, and NH_3 and PM_{10} and weak to moderate positive correlations between CO and $PM_{2.5}$, and CO and PM_{10}. These correlations can help identify relationships between variables and inform further analysis or modeling.

Table 4: Principal component analyses between inorganic contaminants in the atmospheric environment

	Principal 1	Principal 2	Principal 3	Principal 4
Pb	**0.201**	**0.053**	**-0.616**	**-0.169**
NH_3	**0.323**	**0.265**	**-0.453**	**-0.532**
CO	**0.241**	**0.327**	**-0.345**	**-0.523**
$PM_{2.5}$	**0.39**	**-0.542**	**0.329**	**0.586**
PM_{10}	**0.413**	**-0.439**	**-0.157**	**-0.171**
Eigen value	**4.688**	**0.610**	**0.249**	**0.153**
Proportion	**0.698**	**0.112**	**0.045**	**0.026**

Table 4 above showed the results of principal component analyses of the inorganic contaminants in the environment. Principal component 1 showed 69.8% of the variance, with high loadings from Pb, NH_3, CO, $PM_{2.5}$, and PM_{10}, principal component 2 showed 11.2% of the variance, with high loadings from NH3 and CO, but negative loadings from $PM_{2.5}$. principal component 3, showed 4.5% of the variance, with high loadings from $PM_{2.5}$, but negative loadings from Pb and NH_3 while principal component 4, 2.6% of the variance, with high loadings from PM_{10}, but negative loadings from Pb and NH_3. This analysis suggested that the first principal

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component (PC1) captures a significant portion of the variance in the data, with high loadings from most of the variables. This could indicate a strong correlation between these variables. The subsequent principal components (PC2-PC4) capture smaller portions of the variance, with more nuanced relationships between the variables.

Table 5: Contamination factor of inorganic contaminants in the atmospheric environment

Local Govt	Pb	NH_3	CO	$PM_{2.5}$	PM_{10}
Warri	0.002	0.001	0.029	0.122	0.065
Uvwie	0.002	0.001	0.027	0.122	0.066
Udu	0.002	0.001	0.022	0.102	0.057
Okpe	0.002	0.001	0.019	0.088	0.051
Ughelli North	0.002	0.001	0.026	0.110	0.056
Control	0.002	0.001	0.001	0.001	0.001

Table 5 presents the contamination factors for various pollutants in the atmosphere. The contamination factors were measured as follows: lead ranged from 0.002 to 0.002, carbon monoxide from 0.001 to 0.001, particulate matter (PM2.5) from 0.088 to 0.122, and particulate matter (PM10) from 0.051 to 0.066.

According to the classification by Mathias and Stephen (2016), contamination factors are categorized as follows: values less than 1 indicate low contamination, values between 1 and 3 indicate moderate contamination, values between 3 and 6 indicate considerable contamination, and values of 6 or higher indicate very high contamination. This study found that the atmospheric environments exhibited low levels of contamination. However, it is important to note that prolonged exposure to these low contamination levels could lead to serious health issues (Etienajirhevwe and Okoro, 2024).

Table 6: Anthropogenicity of inorganic contaminants in the atmospheric environment

Local Govt	Pb	NH_3	CO	$PM_{2.5}$	PM_{10}
Warri	2.000	2800	176.00	61.20	49.15
Uvwie	2.000	3000	166.00	6090	49.55
Udu	2.000	2400	130.00	51.20	43.05
Okpe	2.000	2600	116.00	43.80	38.15
Ughelli North	2.000	2600	154.00	55.10	42.35
Control	2.000	200	2.00	2.00	0.200

Table 7: Geo accumulation index of inorganic contaminants in air

Local Govt	Pb	NH_3	CO	$PM_{2.5}$	PM_{10}
Warri	0.0004	28.096	0.353	0.012	0.020
Uvwie	0.0004	30.103	0.333	0.012	0.020
Udu	0.0004	24.082	0.261	0.010	0.017
Okpe	0.0004	26.089	0.233	0,009	0.015
Ughelli North	0.0004	26.089	0.309	0.011	0.017
Control	0.0004	2.000	0.004	>0.001	>0.001

Table 6 presents the results of anthropogenicity, while Table 4.7 displays the findings related to geo-accumulation in the atmospheric environment. Anthropogenicity assesses the percentage and extent of human impact on the environment, whereas geo-accumulation indicates the natural buildup of contaminants. Observations reveal that environmental contamination is primarily a result of human activities.

IV. CONCLUSION

All the local government locations examined for inorganic pollutants were found to contain lead ammonia, carbon monoxide and particulate matters. The analytical results indicated that some of these locations were contaminated when compared to critical values established by various monitoring organizations, including the World Health Organization, the Federal Ministry of Environment in Nigeria, the United States Environmental Protection Agency, and the Occupational Safety and Health Administration, as well as in relation to the control site.

V. REFERENCES

[1] Alaa, A. S., Ahmed, A. S. and Ismail, A. E. H. (2009). Determination of Nitrogen dioxide, sulphur dioxide, ozone and ammonia in ambient air using the passive sampling method associated with ion chromatography and potentometric analysis. Air Quality and Atmospheric Health Journal 2**(3):**133-145

[2] Bhatia, S. C. (2019). Environmental pollution and control in chemical process industries, Khanna Publishers, p.163.

[3] Brimblecombe, P. (2020). The Big Smoke, A history of air pollution in London since medieval times, Routledge, London.

[4] Burton, G. A. and Robert, P. (2020). Storm water effects handbook. A toolbox for watershed managers, scientists and Engineers CRC/Lewis Publishers, New York, p.329.

[5] Canter, L. (2020). Environmental impact of agricultural production activities, Lewis Publishers Inc., Chelsea, Michrigam, pp.169-209.

[6] Ekeayanwu, C.R (2006). Pollution of the Warri Environment – HND final year project, Department of industrial safety and environmental technology, Petroleum training institute, Effurun, Nigeria.

[7] Environment Agency (2022). Report into an Air Pollution Episode – Sulphur Dioxide, Midlands and South Yorkshire, p. 278

[8] Etienajirhevwe, O.F and Okoro, D (2024) Contamination / Pollution Assessment of Soil Around Tank Farms in Oghareki – Oghara Community in Ethiope West Local Government Area of Delta State, Nigeria. Ethiopian Journal of Environmental Studies & Management 17(2): 399 – 410, 2024. doi: https://ejesm.org/doi/v17i3.10

[9] European Environment Agency (2022). Guidelines for Defining and Documenting Date on costs of possible environmental protection Measures, Internet site www.eea.euint,environmentalthemes, Assessed July 27, 2024.

[10] Harrop, D.O. (2016) Tackling air pollution problems with computer models, London Environmental Bulletin, (4), 11-12.

[11] Harrop, D.O. (2022). Air Quality Assessment, in Petts J. (Ed). Handbook of Environmental Assessment, Environmental Impact Assessment: Process, Methods and Potential, Blackwell Science, Oxford Pp.252-272.

[12] Hathaway, G.J., Proctor, N.H., Hughes, J.P and Fischman, M.L (2022) Proctor and Hughes' chemical hazards of the workplace. 3rd edition. New York, NY: Van Nostrand Reinhold.

[13] Khandekar, R. N., Kelkar, D. N. and Vohrs, K. G. (2022). Lead, Cadmium, Zinc and Iron in the atmosphere of greater Bombay, Journal of Atmospheric. Environment, 14:457-461.

[14] Onwukeme, V. I. and Etienajirhevwe, O. I. (2014). Determination of levels of some inorganic gaseous contaminants in Warri and Effurun Environs in Delta State, Nigeria, Ethiopian Journal of Environmental Science and Management 7**(6)**: 619-627.

[15] Onwukeme, V.1 and Etienajirhevwe, O.F (2020). Determination of Metal Concentration in Air, Soil and Water Samples at Some Selected Flow Stations in Delta State, Nigeria. American Journal of Physical Chemistry, 9(1):9-15.doi: 10.11648/j.ajpc.20200901.12