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Study of Selected Inorganic Contaminants in Atmospheric Environment around Selected Local Governments Area of Delta State, Nigeria

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ABSTRACT

This study covers the determination of selected inorganic gaseous contaminants in the atmospheric environment of selected Local Government Area which include Warri, Uvwie, Udu, Okpe and Ughelli of Delta State in Nigeria. The inorganic contaminants studied are sulphur dioxide, nitrogen dioxide and ozone. Air samples were collected for a period of one year and were analyses for the presence of the inorganic contaminants by the use of Uv / Visible spectrophotometer and data were presented as mean triplicate of analyses. Results of analyses showed sulphur dioxide in the range of 0.198 – 0.552µg/m^3 for the months of investigations and 0.314 – 0.554µg/m^3 for local governments of investigations, nitrogen dioxide in the range of 0.358 – 0.882µg/m^3 and 0.661 – 0.952µg/m^3 for months and local governments of investigations respectively while ozone was below detection limit. Based on the geo – accumulation and anthropogenic test, the contaminated was found to be as results of human activities in the various local governments.

Keywords: Environment, Pollution, Contaminants, Local Government

INTRODUCTION

Pollution refers to the presence of one or more contaminants (pollutants) in sufficient quantities and for extended periods that can harm human health, plant or animal life, or property. It can also disrupt the enjoyment of life, property, or business activities in an unreasonable manner. (Canter, 2020).

The atmospheric environment is the layer of gases that envelops the Earth, serving as a boundary between its surface and the emptiness of space. (Bhatia, 2019). Concerns regarding the quality of the atmosphere have likely existed since the dawn of humanity. With the invention of fire, air pollution emerged as a significant issue. (Brimblecombe, 2020).

Gaseous contaminants have been detected in the environments of various industries, including refineries, ports, and areas near busy roads, as well as in urbanized regions overall. (Onwukeme and Etienajirhevwe, 2020). The concentration of certain contaminants acts as an indicator of atmospheric pollution levels. (Khandekar *et. al.*, 2022).

An examination of environmental pollution across various countries indicates a swift rise in certain regions, while others are experiencing a decrease. Notably, Northern Ireland exhibits high levels of sulfur dioxide, prompting worries that this may be associated with sulfur emissions from a lagoon located near a monitoring station. (Burton and Robert 2020)

An examination of environmental pollution in various countries indicates a swift rise in certain regions, while others are experiencing a decrease. Notably, Northern Ireland exhibits high levels of sulfur dioxide, prompting worries that this may be associated with sulfur emissions from a lagoon located near a monitoring station. (Harrop, 2016). Air pollutants can originate from various types of anthropogenic sources, including point or stationary sources, area sources, and mobile (linear) sources. Each type of source has unique emission characteristics. Point sources are defined areas, such as industrial complexes, while mobile sources encompass vehicles, aircraft, and similar entities. Emissions from these sources can be categorized as controlled, uncontrolled, accidental, intentional, or fugitive. (Harrop, 2022). The aim of this work is to determine some pollutants in air samples at some selected locations in Effurun, Warri, Udu, Ughelli, and Okpe local Government areas with objectives to determine the concentrations of sulphur dioxide, nitrogen dioxide and ozone in the atmospheric environment of Effurun, Warri, Udu, Ughelli, and Okpe local Government areas of Delta State, Nigeria.

METHODOLOGY

Sample collection

Nitrogen dioxide (NO_2) samplings

Nitrogen Dioxide component was collected by treating NO_2 sampler with a standard solution prepared by mixing 7.90g sodium iodide (NaI) with 0.88g sodium hydroxide (NaOH) into 100mL methanol which was stirred in an ultrasonic bath (Alaa *et. al.*, 2009). The sampler was then mounted on an average height of 2.0 meters and was allowed to stay for a period of fourteen days.

Sulphur dioxide (SO_2) samplings

Sulphur Dioxide component was collected by treating and impregnating the SO_2 samplers with a standard solution prepared by dissolving 5.60g Potassium hydroxide (KOH) into 50.0mL methanol and mixed with 10.0mL glycerol which was made to 100mL by methanol (Alaa *et. al.*, 2009). The samplers were mounted at average height of 2.0meters from ground and were allowed to stay for a period of fourteen days.

Ozone (O_3) samplings

Ozone components was collected by treating and impregnating the ozone samplers with a standard solution of ethene which was then mounted at an average height of 2.0meters from ground for a period of fourteen (14) days (Onwukeme and Etienajirhevwe, 2014).

Harvesting of samplers

All the samplers mounted were harvested after a period of fourteen (14) days. The samplers which were initially open for in-flow of air were then closed with special caps to avoid any form of contamination and desorption. The samplers were placed into tightly closed special bags and were kept in a refrigerator at a controlled temperature until they were processed. The glass fibre filters used for heavy metal component collection were placed in an air tightened container in a black polythene bags. All the samples were handled with all carefulness to avoid contamination.

Instrumental analyses

Sulphur dioxide (SO_2)

The harvested adsorbent paper containing the SO_2 componentwas cut into pieces and were digested and extracted by bubbling them in solution of 0.05% hydrogen peroxide (H_2O_2) in distilled water using magnetic stirrer for a period of thirty minutes and was filtered. 10mL of the extracts were measured into a clean cell and one content of a "sulfaver 4" (a sulphate test tablet) was added to the content (to ensure colour development of SO_2 in the samples) and was thoroughly swirled to ensure proper mixing. The resulting solution were subsequently analyzed for SO_2 concentration by using UV/visible spectrophotometer (Perkin Elmer Lambada E = 301) with their concentration recorded at a wavelength of 608nm. Blank determination was carried out in the same manner (Onwukeme and Etienajirhevwe, 2014).

Nitrogen dioxide (NO_2)

Harvested adsorbent paper containing NO_2 was cut into pieces and digested with a solution of N-(1-Napthl) ethylenediamine dihydrochloride for a period of thirty minutes using a magnetic stirrer (ASTM, 2015). This was then filtered into a volumetric flask. 25mL of the filtrate was measured into a measuring cylinder followed by the addition of "Nitraver 6" reagent powder pillow to ensure NO_2 development, stoppered and was homogenized and subsequently analyzed with a UV/visible spectrophotometer at a wavelength of 550nm. Blank determination was also carried out in the same manner (Onwukeme and Etienajirhevwe, 2014).

Ozone (O_3)

The harvested adsorbent paper containing ozone component were cut into pieces and were extracted using deionized water over low heated using magnetic stirrer, cooled and were filtered into conical flasks. 40mL of the extracts were measured into conical flasks followed by the addition of an indigo ozone reagent ("Accu vac Ampul") and were subsequently analyzed for ozone concentration using UV/visible spectrophotometer at a wavelength of 450nm, Blank determination was carried out in the same manner. (Onwukeme and Etienajirhevwe, 2014)

Quality assurance / quality control

Strict quality assurance and quality control measures were performed during the field sampling and laboratory analyses. All sampling containers were properly sterilized and all equipment calibrated. The concentration of targeted parameters in the laboratory blanks and procedural blanks were all below the detection limits..

RSULTS AND DISCUSSIONS

Results

Tab

le 1: Mean inorganic contaminants and particulate matter (µg/m^3) in air as per months of investigation

Months	SO_2	NO_2	O_3
January	0.427cd	0.753fg	<0.001
February	0.328cd	0.413cd	<0.001

March	0.366cd	0.526de	<0.001
April	0.198b	0.358cd	<0.001
May	0.338cd	0.513de	<0.001
June	0.258b	0.427cd	<0.001
July	0.301cd	0.573de	<0.001
August	0.291bc	0.451cd	<0.001
September	0.311cd	0.451cd	<0.001
October	0.436d	0.671f	<0.001
November	0.538de	0.832fg	<0.001
December	0.552de	0.882fg	<0.001
Control	0.017a	0.038a	<0.001

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

Local Govt	**SO_2**	**NO_2**	**O_3**
Warri	**0.583cd**	**0.856e**	**0.001a**
Uvwie	**0.600cd**	**0.952ef**	**0.001a**
Udu	**0.432c**	**0.803e**	**0.001a**
Okpe	**0.314c**	**0.661cd**	**0.001a**
Ughelli North	**0.554cd**	**0.850e**	**0.001a**
Control	**0.017a**	**0.038a**	**0.001a**

Sulphur dioxide was found in the range of 0.198 – 0.552µg/m^3 for the months of investigations and 0.314 – 0.554µg/m^3 for local governments of investigations. The highest concentration of sulphur dioxide was recorded in the month of December while the lowest was in the month of April. The months with high concentration of sulphur dioxide (0.427 – 0.552µg/m^3) are October, November, December and January which are regarded as dry season in Nigeria where the atmosphere is known to be concentrated with various form of gases as a result of low rain fall and humidity. On the other hand, the month of February to September recorded low sulphur dioxide concentrations (0.198 – 0.311µg/m^3). The period of these months is the wet season with high rainfall and humidity which tend to dilute any form of gaseous concentration in the atmosphere. The results of the monthly investigation (both wet and dry season) were higher than the control site with 0.017µg/m^3 which suggested contamination and / or pollution of the atmosphere with sulphur dioxide. Statistical analyses between the months, season and control showed significant differences which also showed that the atmospheric environment is contamination and / or polluted with sulphur dioxide. Figure 1 below showed the distribution of sulphur dioxide as per months of investigation compared with that of the control

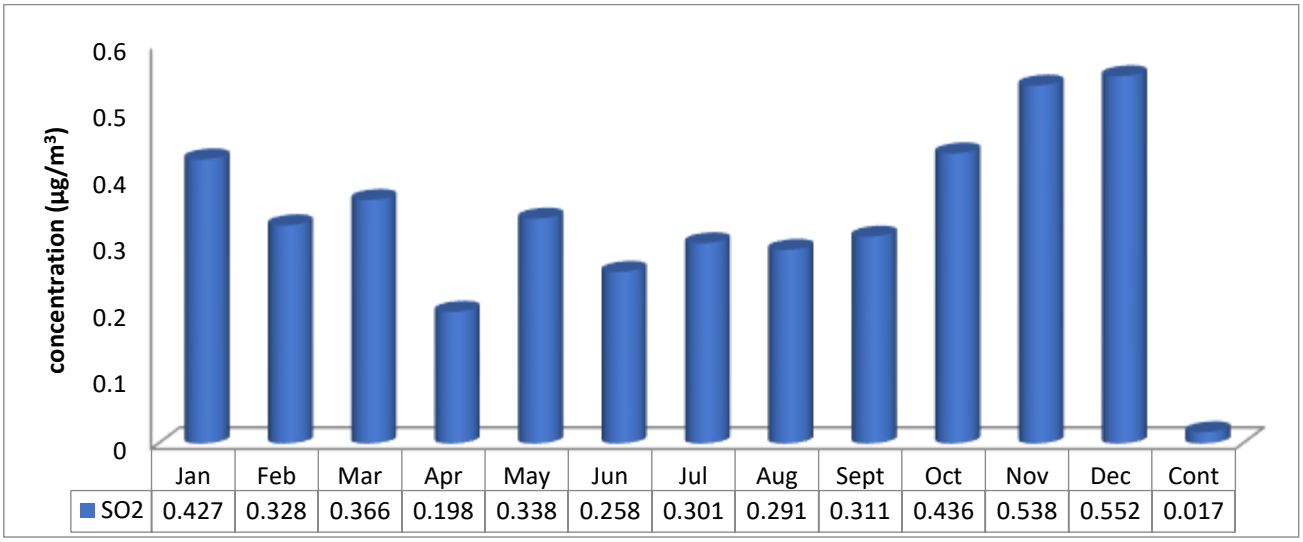

Figure 1: Concentration of SO_2 in air with respect to months

For the local government of investigation, the highest concentration of sulphur dioxide was recorded at Uvwie (0.600µg/m^3) followed by Warri (0.583 µg/m^3), Ughelli North (0.554µg/m^3, Udu (0.432µg/m^3) while the lowest was Okpe (0.314µg/m^3). The results obtained from the various local governments of investigations were all higher than that of the control (0.017µg/m^3) which showed that there is contamination and / or pollution of the atmospheric environment with sulphur dioxide as statistical analysis also showed that there is a significant difference between values obtained at the various local governments and that of the control. Inter – local government statistical analyses also showed significant differences between the concentrations obtained from each local government except for Warri and Uvwie which are statistically the same. Figure 2 below showed the distribution of sulphur dioxide in the various local governments of investigation in comparison with that of the control.

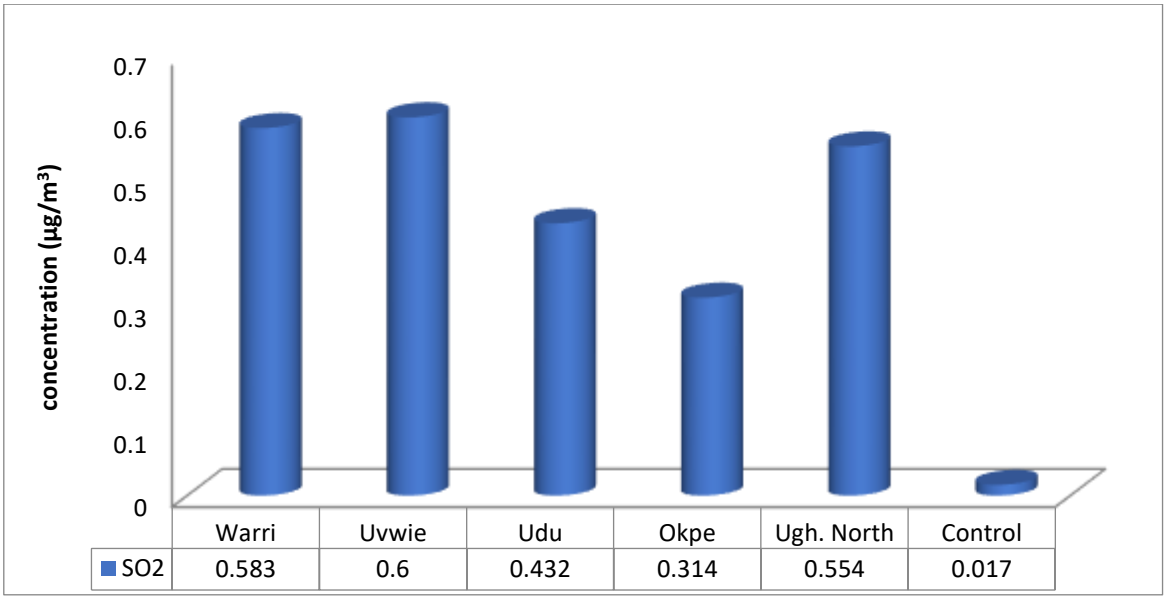

Figure 2: Concentration of SO_2 in air with respect to local governments

The results of the sulphur dioxide in the environment can generally be attributed to the various activities taking place in the various study locations which include forest and wild fires which emits sulphur dioxide, industrial processes around refineries, vehicle emissions especially those burning diesel or gasoline could release sulphur dioxide (though less significant), agricultural activities which involves the use of fertilizers and pesticides containing sulphur can release sulphur dioxide when applied to crops or soil and landfills and waste incineration which can emits sulphur dioxide especially when they contain high level of sulphur.

The results of this study were lower than those of Onwukeme and Etienajirhevwe (2014) who determined sulphur dioxide in Warri – Effurun and its environs and Ekeayanwu (2006) who determined sulphurn dioxide in Warri environs. It is worthy to note that exposure to concentration values above the permissible limit for ambient air would result to health effects such as respiratory irritant (Environment Agency, 2022), stimulation of nerves in the lining of the nose, throat and airways of the lungs. It has also been reported that people suffering from asthma may be susceptible to the adverse effect of sulphur dioxide. Though some locations are polluted and some not or slightly polluted, it should be noted that exposure to sulphur dioxide concentration of 20ppm causes eye irritation and coughing in healthy adults, 15µg/m^3 for 1 hour decreases mucoduary activity, 5µg/m^3 causes throat irritation in healthy adults at rest, 0.19µg/m^3 for 24hours leads to aggravation of chronic respiratory disease in adults while 0.07µg/m^3 for animal exposure lead to aggravation in children (Harrop, 2022). It should also be noted that one of the primary pollutant of principal concern is the formation of acid rain is sulphur dioxide which can react with oxides of Nitrogen and oxidized to form sulphuric acid either in the atmosphere or after deposition (Onwukeme and Etienajirhevwe 2014).

Sulphur dioxide can also have significant effects on the environment as acid rain can harm crops, forests, and aquatic ecosystems by altering soil pH and releasing toxic substances; sulphur dioxide can react with other pollutants to form particulate matter, haze, and smog; sulphur dioxide can contaminate water sources, affecting aquatic life and human consumption; acidic water can leach heavy metals from soil and rocks, further polluting waterways; excessive sulphur dioxide can alter soil chemistry, reducing fertility and affecting plant growth; acidic soils can lead to nutrient deficiencies, reduced crop yields, and increased soil erosion; sulphur dioxide can damage forests, reducing tree growth and increasing susceptibility to disease and pests; acid rain can alter the composition of ecosystems, favoring acid-tolerant species over others (Hathaway et. al., 2022). Acid rain can corrode buildings, bridges, and other infrastructure, increasing maintenance and repair costs and can also damage cultural heritage sites, such as monuments and historic buildings. Sulphur dioxide can influence cloud formation and Earth's energy balance, potentially affecting global climate patterns. However, the net effect of sulphur dioxide on climate change is still being researched and debated.

Nitrogen dioxide gas was found in the atmospheric environment in the range of 0.358 – 0.882µg/m^3 and 0.661 - 952µg/m^3 for months and local governments of investigations respectively.

Results of monthly investigations showed high concentration of nitrogen dioxide in the months of October through January with concentration range of 0.671 – 0.882µg/m^3 while low concentrations were obtained through the months of February – September. The highest concentration was obtained in the

month of December while the lowest was in the month of April. Results obtained for all the months of investigations were higher than that of the control (0.038µg/m^3) suggesting contamination and / or pollution of the atmospheric environment. It was also observed that results of the months of dry season (October – January) were higher than those of the wet season (February – September). This showed that the atmosphere was more concentrated with nitrogen dioxide gas during the dry than in the wet season. The reason for this is that during the wet season, rain and humidity tend to dilute the amount of nitrogen dioxide and the atmosphere and convert it to other form and bring it to the ground / soil.

Statistical analyses of the results of monthly investigation with that of the control showed that there was a significant difference meaning that there is contamination and / or pollution of the atmosphere. Inter monthly comparison also showed significant difference which means that the contamination and /or pollution of the atmosphere changes from month to months which could also be due to the density of the activities going on within the months of investigations. Figure 3 below showed the monthly variations of the concentration of nitrogen dioxide in the atmospheric environment in comparison with that of the control.

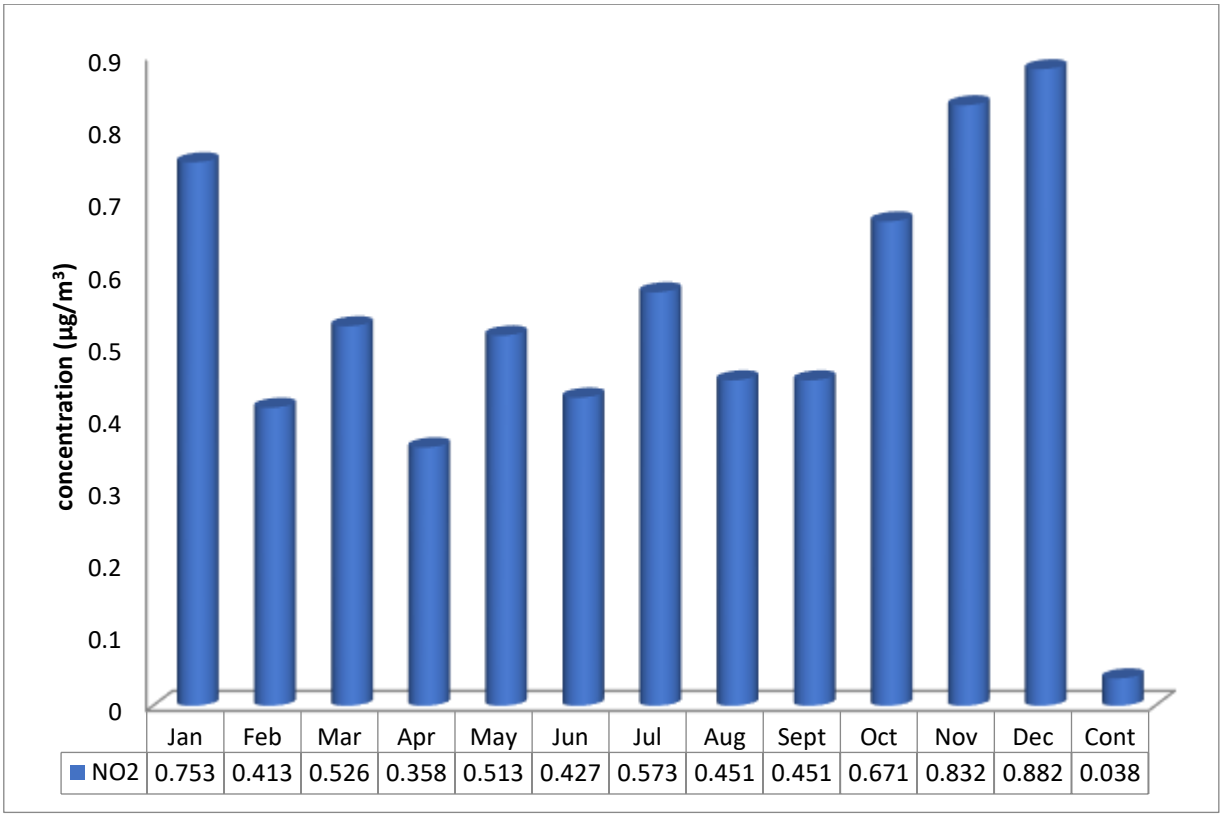

Figure 3: *Concentration of NO_2 in air with respect to months*

Results of nitrogen dioxide from the various local governments were found in the range of 0.661 – 0.952µg/m^3 with Warri, Uvwie, Udu, Okpe and Ughelli North recording 0.856, 0.952, 0.803, 0.661 and 0.850µg/m^3 respectively. The highest concentration was recorded at Uvwie while the lowest was at 0.661µg/m^3. The concentration of nitrogen dioxide in the various local governments were all higher than that of the control suggesting that there is contamination and / or pollution of the atmospheric air of the various local governments. Statistical analyses showed that there is a significant difference between the various local governments and the control and among the local government themselves Figure 4 below showed the distribution of the concentration of nitrogen dioxide in the various local governments compared to that of the control.

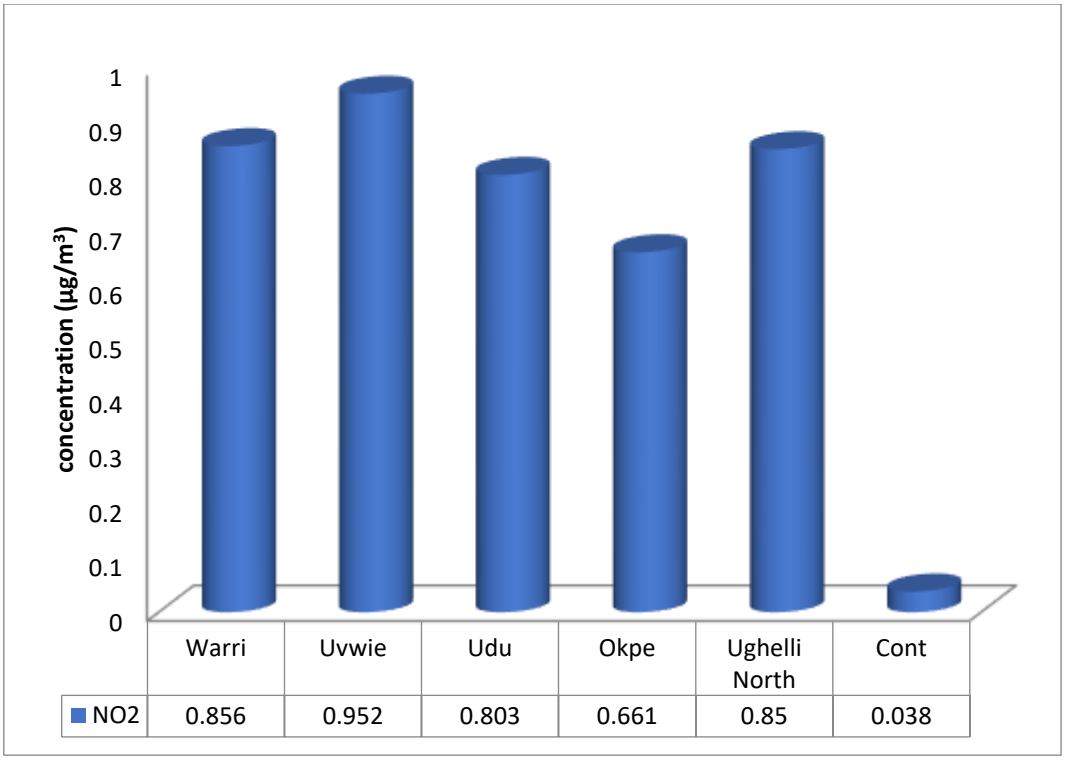

Figure 4: Concentration of SO_2 in air with respect to local governments

The of this present study were higher than those of Onwukeme and Etienajirhevwe (2014) that studied the presence of inorganic gases in Warri – Effurun and its environs and Ekeayanwu (2006) who studied the presence of nitrogen dioxide in Warri and Effurun metropolis.

Some of the major sources of nitrogen dioxide in the atmospheric environment can be attributed to the presence of vehicles such as cars, trucks, buses and motor cycles that emit nitrogen dioxide through their exhaust pipes during transportation; fossil fuel based power plants such as those burning coal, oil and gas which release the gas into the atmosphere and various industrial activities like metal processing, chemical manufacturing and oil refining.

It is important to highlight that the presence of nitrogen dioxide in all study locations indicates that prolonged exposure to these levels can be harmful to human health. Long-term exposure to concentrations that are either below or above the critical threshold may result in reversible effects on lung function and airway responsiveness, as well as heightened sensitivity to natural allergens. Additionally, exposure to nitrogen dioxide may increase the risk of respiratory infections in children and could lead to diminished lung function later in life. At higher concentrations, nitrogen dioxide can trigger acute inflammation in the respiratory pathways. (Onwukeme and Etienajirhevwe, 2014). Individuals with asthma are highly sensitive to air quality, with exposure to concentrations around 50 µg/m³ for just thirty minutes resulting in minor changes in standard lung function indices. In contrast, a concentration of approximately 1800 µg/m³ would be required to elicit a similar response. The relationship between exposure and response to nitrogen dioxide is inconsistent; for instance, exposure to 560 µg/m³ may trigger a reaction, while doubling that concentration might not. Additionally, responses may not recur as concentrations approach or exceed 1800 µg/m³, although the reasons for this phenomenon remain unclear. (European Environment Agency, 2022).

Ozone concentrations were below detection limit in all the study locations and the absence of ozone in these location justified the statement of Harrop (2022) that low and / or absence of ozone is always observed where there is high concentration of NO_2 as O_3 presence are used for the conversion of NO to NO_2. The study locations are therefore found to be free from ozone

Table 3: Correlation between the inorganic contaminants in the atmosphere

	SO_2	**NO_2**	**O_3**
SO_2	**1**		
NO_2	**0.786**	**1**	
O_3	**0.333**	**0.218**	**1**

Table 3 above showed results of the correlation matrix between the inorganic contaminants found present in the atmospheric environment. Observations showed that SO_2 and NO_2 have a moderate positive correlation (r = 0.786), indicating that they often appear together in the atmosphere, high correlation for SO_2 and O_3 (r = 0.333) and between NO_2 and O_3 (r = 0.218)

Table 4: Principal component analyses between inorganic contaminants in the atmosphere

	Principal 1	Principal 2	Principal 3	Principal 4
SO_2	**0.407**	**0.279**	**0.683**	**-0.465**
NO_2	**0.609**	**0.657**	**-0.067**	**0.572**
O_3	**0.238**	**0.026**	**-0.129**	**-0.292**

Table 4 above showed the results of principal component analyses of the inorganic contaminants in the environment. Principal Component 1 (PC1) showed 69.8% of the total variance and has high loadings for SO_2, NO_2 and O_3 which showed that these pollutants are highly correlated with each other and may be related to a common source or process.

Table 5: Contamination factor on inorganic contaminants in air

Local Govt	SO_2	NO_2	O_3
Warri	**0.029**	**0.021**	**0.001**
Uvwie	**0.030**	**0.024**	**0.001**
Udu	**0.022**	**0.020**	**0.001**
Okpe	**0.016**	**0.017**	**0.001**
Ughelli North	**0.028**	**0.021**	**0.002**
Control	**0.001**	**0.001**	**0.001**

Table 5 showed the contamination factor of the contaminants found in the atmospheric environment. The contamination factor o was found in the range of 0.016 – 0.030, 0.017 – 0.024, 0.001 – 0.002 for sulphur dioxide, nitrogen dioxide and ozone respectively.

Contamination factors were categorized according to Mathias and Stephen (2016). Values < 1 are low contamination, 1≤CF<3 are moderately contaminated, 3≤CF≥6 are considerably contaminated with ≥ very highly contaminated. From this study it showed that the atmospheric environments have low contamination. Though low contamination was observed in the various locations, it worthy to note that long time accumulated would pose serious health condition (Etienajirhevwe and Okoro 2024)

Table 6: Anthropogenicity (Apn) of inorganic contaminant in the atmosphere

Local Govt	SO_2	NO_2	O_3
Warri	**9.700**	**14.30**	**0.500**
Uvwie	**10.00**	**15.90**	**0.500**
Udu	**7.200**	**13.40**	**0.500**
Okpe	**5.200**	**11.00**	**0.500**
Ughelli North	**9.200**	**14.10**	**0.500**
Control	**0.300**	**0.600**	**0.500**

Table 7: Geo accumulation (Igeo) of inorganic contaminants in the atmosphere

Local Govt	SO_2	NO_2	O_3
Warri	**0.019**	**0.029**	**0.001**
Uvwie	**0.002**	**0.032**	**0.001**
Udu	**0.014**	**0.027**	**0.001**
Okpe	**0.011**	**0.022**	**0.001**
Ughelli North	**0.019**	**0.028**	**0.001**
Control	**0.001**	**0.001**	**0.001**

Table 6 showed results of anthropogenicity while 7 showed that of geo accumulation as was found in the atmospheric environment. Anthropogenicity measures the percentage and / or extent of anthropogenic input on the environment while geo accumulation is an indication of the natural accumulations of contaminants in the environment. Observation showed that the contamination of the environment is due to the anthropogenic activities.

CONCLUSION

Among the study locations, Warri recorded the highest level of contamination followed by Warri, Udu, Ughelli while Okpe was the least. The dry season was found to be more contaminated than the wet season. Based on the geo – accumulation and anthropogenic test, the contaminated was found to be as results of human activities in the various local governments. Breathing air is essential for life, making it crucial to manage this resource effectively for a sustainable future. The management of air as a natural resource should involve exploring methods and techniques grounded in solid scientific principles, with a focus on carefully addressing the challenges posed by our already polluted atmosphere.

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