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# Evaluation of Airborne Particulate Matter in Some Selected Cities in Delta State, Nigeria

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## ABSTRACT

*Air pollution in Nigeria and many other countries all over the world is a big problem of the 21st century caused by globalization and industrialization. Oil exploration in the Niger Delta region, including Delta state, has grossly reduced the quality of air in the region. This research work focused on evaluation of air borne particulate matter in major cities such as Warri, Ughelli, Sapele and Ugbenu in Delta State. This was done to determine their concentrations, impacts of the pollutants, health implications and possible management measures on lives and environment. Particulate matter in air samples were obtained using Casella microDust Pro Aerosol monitoring system and monitored for a period of one year covering both wet and dry seasons. Polyurethane Foam Filter (PUF) gravimetric adapter was used to provide size-selective sampling for $PM_{10}$ and $PM_{2.5}$ fractions. The results showed that Total Suspended Particulate (TSP), Particulate Matter 10 (PM10) and Particulate Matter 2.5(PM2.5)*. *ranged between 1.02 – 12.36 mg/m$^3$ (average 5.03 ± 0.38), 0.17 – 10.5 mg/m$^3$ (average 2.13 ± 0.26) and 0.44 – 6.64 mg/m$^3$ (average 2.17 ± 0.20) respectively; clearly exceeded the regulatory limits of Federal Ministry of environment (FMENV) and National ambient air quality standards (NAAQS) in both seasons. The study also showed that Matrix (Warri), Amukpe (Sapele) and Ekakpamre (Ughelli) recorded the highest concentration of particulates in the three cities studied. Higher values were obtained in the dry season than the wet season. The correlation of meteorological parameters with TSP, $PM_{10}$ and $PM_{2.5}$ shows that only temperature had a weak, but significant, correlation while other parameters did not show any correlation with the concentration of the particulates. The low correlation or absence of correlation between the particulates and meteorological parameters suggests that anthropogenic contributions are significant to their concentration in the study areas. This can be attributed to high level of fuel combustion from motor vehicles, power generation and industrial facilities. The pollution could also be due to dusty industries, windblown dust, crushing and grinding operations. Ugbenu, the control location also recorded high level of particulates; this is due to residential fireplace, wood stoves, unsuspended dust from untarred road, bush burning and windblown dust predominant in the area.*

**Key Words***:* Air pollution, Airborne Particulates, *Quality of air, Polyurethane Foam Filter, Oil exploration.*

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## 1. INTRODUCTION

Air pollution arises from anthropogenic activities due to quest for a better standard of living and the utilization of natural resources for rapid industrialization and urbanization (Abam et al., 2009, Kampa and Castanas, 2008). Air pollution could also be due to natural sources (volcanic eruption, whirlwind, earthquake, decay of vegetation, pollen dispersal and forest fire) (Garg et al., 2006). These activities release some gaseous emissions and particulates that contaminate air; and when in high concentrations could cause damage to environment and human health (Rai et al., 2011). However pollutant becomes toxic when the concentration is above the allowable concentration in ambient air (Gurjar et al., 2004).Air pollution problems have continued to receive a great deal of interest worldwide due to its negative impacts on health effects, property damage and environmental effects (like smog, acid rain, radiation and ozone layer depletion) (EPA, 2014; Francis et al., 2019). Air pollution is a serious threat to environmental health in many cities of the world today (Jonathan, et al 2000).There is need for regular studies and proper monitoring of emission from facility generating gaseous waste to protect lives and environment against toxic air pollutants(Al-Salem et al, 2006, Pfeiffer, 2005). Due to the chemical complexity of airborne particles and health concern, it becomes imperative to consider the composition and sources of selected primary and secondary particulates deemed to be of health concern.

Particulate matter is the term given to the tiny particles of solid or semi-solid material found in the atmosphere as suspended mixtures. The chemical complexity of airborne particles makes it imperative to consider the composition and sources of selected primary and secondary particulates deemed to be of health concern. Primary particulates are introduced into the atmosphere from a variety of natural and anthropogenic sources. Secondary particulates tend to form in the atmosphere as a result of chemical processes (Owoade et al., 2012). Ambient concentrations of coarse particulate matter with an average diameter of 10 micrometers constitute of PM10 or inhalable particulates and fine particles of less than 2.5 micrometers in diameter constitute of PM2.5or Respirable particulates (Efe, 2006).These could arise from biomass burning, emissions from vehicular traffic, generator emissions, bush burning, smelting industries, paper manufacturing industries as well as dust from unpaved roads (Efe, 2008).The chemical complexity of airborne particles and adverse health effects pose a great threat to health (WHO, 2005). Adverse health effects include cough, asthma, renal failure, and infertility (Faktel et al., 2015). Extreme air pollution conditions that affect humanity include high blood pressure, heart or lung disease, respiratory damage and premature death (Gupta et al., 2006).

Oil exploration in the Niger-Delta region of Nigeria has grossly reduced the quality of air in the region and the level of industrialization does not commensurate with environmental studies and monitoring (Orubu, 2000; Tawari et al., 2015).This research was focused on evaluation of Total Suspended Particulate matter (TSP), Inhalable particulate matter (PM10) and Respirable particulate matter (PM2.5) at Warri, Ughelli, Sapele and Ugbenu in Delta State, Nigeria. This was done to determine their concentrations, impacts of the pollutants, health implications and possible management measures on lives and environment. Although there have been some pioneer studies on PM2.5, PM10 and TSP concentrations in Delta state (Ede et al.,2010), the present research is a one-year study that captures seasonal variation in the levels of the particulates in these highly-industrialized cities.

## 2.0 MATERIALS AND METHOD

### 2.1 Study Area

This study was carried out in Delta state, Nigeria. Four cities including Warri, Ughelli, Sapele and Ugbenu were selected for this study. A map of the study area showing the sampling locations is shown in Fig. 1. Ugbenu is the control location. The common air pollution sources in the area are biomass combustion, bush burning, automobile emissions, generator emissions, pipeline explosions, industrial emissions and gas flaring.

Warri is one of the major cities of petroleum activities and businesses in the southern part of Nigeria. It shares boundaries with Ughelli, Sapele, Okpe, Udu and Uvwie. It is a commercial city of Delta State with a population of over 311,970 people from 2006 census (FRN, 2007). Ughelli is a town in Delta state, Nigeria. The town was originally an agricultural center, but now, oil industries, petroleum extraction and also glass bottle factory are functional in the area. Ughelli has a population of 82,994 people from 2006 census. Sapele is a city in Delta state with population of 142,652 people from 2006 census. Sapele was established by the mid- 19th century as a trading village, which was occasionally visited by Europeans. Presently, the city has one of Nigerian's major ports. There are many industries in Sapele, which include the processing of timber, rubber, palm oil, furniture, tamarind balm, footwear, flour mill and petroleum industries. A high temperature of 34 $^{o}$C, low temperature of 22 $^{0}$C, mean temperature of 27 $^{0}$C, dew point of 22 $^{0}$C, pressure of 1010 mbar and visibility of 12 km was recorded at the study area. Annual rainfall of 2135 mm was recorded for Sapele, Ughelli recorded 2312 mm and Warri recorded 2605 mm. Ugbenu the control location, is situated in Delta State at the boundary between Delta State and Edo State.

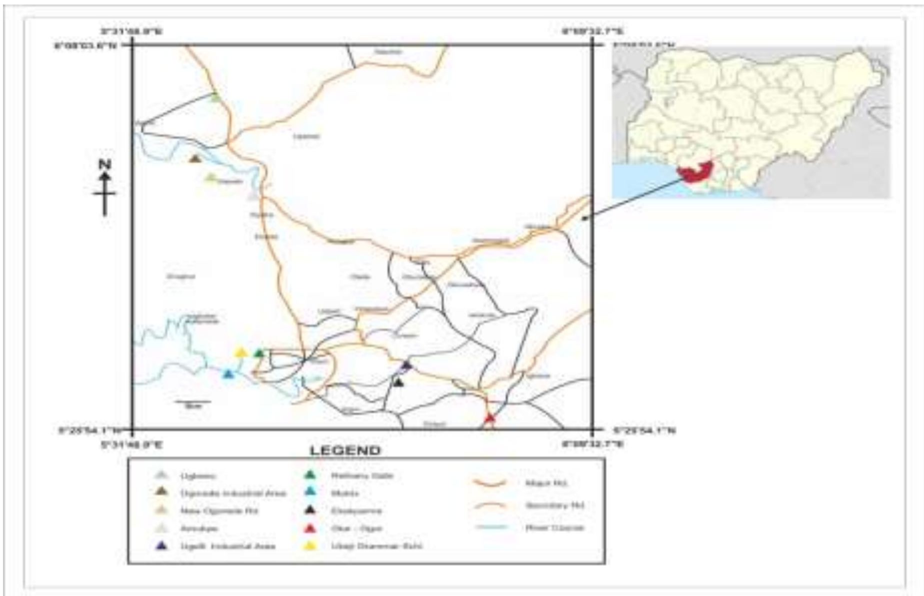


**Figure 1: Map of the study area showing sampling locations**



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## 3.0 RESULTS AND DISCUSSION

### 3.1 Annual concentration of the Particulates

The annual mean concentration of TSP measured within the sampling sites range from 4.02 mg/m$^3$ – 7.10mg/m$^3$. The least value was recorded at Refinery Entrance while the highest value was recorded at Otorgor. It can be seen from Table 2 that all the figures obtained clearly exceeded the regulatory limits of Federal Ministry of environment (FMENV) of 250µg/m$^3$ (0.25mg/m$^3$). The factors responsible for these high values could include high rate of biomass combustion, bush burning, automobile emissions, generator emissions, windblown dust, industrial emissions and gas flaring at the sampling locations (Akuro, 2012).

The annual mean concentration of Inhalable particulate measured within the sampling sites range from 1.633 mg/m$^3$ – 2.830 mg/m$^3$. The least value was recorded at Refinery Entrance while the highest value was recorded at Matrix. It can be seen from Table 2 that all the figures obtained clearly exceeded the regulatory limits of National ambient air quality standards (NAAQS) of 150µg/m$^3$ (0.150mg/m$^3$) for $PM_{10.}$ The study carried out by (Qiao et al, 2015, Wang et al, 2013, Zhang et al, 2014, Huang et al, 2015) also recorded that $PM_{2.5}$ and $PM_{10}$ were two major pollutants in Chengdu during the study period, similar to most cities in China (e.g., Beijing, Wuhan, and Xi'an) that exceeded the standards. The control site recorded very high values at the peak of dry season (December, January, February and March). This could be as a result of windblown dust from far and near polluted sites combined with biomass combustion and bush burning which are rampant at the control location. Comparing with the report obtained from review of particulate matter at selected locations in Nigeria from 1985 – 2015; Results showed that $PM_{2.5}$ concentration ranged from 5-248 µg/m$^3$, while $PM_{10}$ concentration ranged from 18-926 µg/m$^3$, revealing that about 50% of the particulate matter loads in Nigeria exceeded both the WHO (25 µg /m$^3$, 50 µg/m$^3$) and NAAQS (35 µg/m$^3$, 150 µg/m$^3$) guideline limits for $PM_{2.5}$ and $PM_{10}$ respectively.

Respirable particulate measured across the sampling sites had an annual mean concentration that range from 1.556 mg/m$^3$ – 3.530 mg/m$^3$. The least value was recorded at Refinery Entrance while the highest value was recorded at Otorgor. It can be seen from Table 2 that all the figures obtained clearly exceeded the regulatory limits of NAAQS of 35 µg/m$^3$ (0.035 mg/m$^3$) for $PM_{2.5}$. This agrees with segregated air pollution studies carried out in Port-Harcourt, Rivers State, Sapele in Delta State, Obaretin and Isoko in Edo State that all selected locations in the South-South zone exceeded the WHO and NAAQS guideline criteria values for $PM_{2.5}$ and $PM_{10}$ (Obio et al, 2013, Ediagbonya et al, 2014, Aziakpono et al, 2013, Ediagbonya et al, 2012).

Matrix, Otorgor and New Ogorode Area locations recorded the highest concentration of the particulates in the cities studied; though all the locations sampled exceeded the regulatory limits for the period of sampling.

**Table 1: Annual Concentration (mg/m$^3$) of Particulates**

| City | Sampling Location | TSP | Inhalable | Respirable |
|---|---|---|---|---|
| **Warri** | Refinery Entrance | 4.02± 0.41 | 1.66± 0.18 | 1.56 ± 0.14 |
| | Ubeji Gr. School | 4.07± 0.41 | 1.96± 0.24 | 1.85± 0.18 |
| | Matrix | 5.00 ± 1.01 | 2.83 ± 0.97 | 2.02± 0.16 |
| **Ughelli** | Ughelli Ind. Area | 4.27± 0.39 | 2.16±0.21 | 1.75± 0.18 |
| | Ekakpamre | 4.54± 0.28 | 1.95± 0.21 | 1.97± 0.11 |
| | Otorgor | 7.10± 0.47 | 2.35± 0.14 | 3.53±0.33 |
| **Sapele** | Ogorode Ind. Area | 4.04± 0.35 | 2.09± 0.03 | 1.57± 0.23 |
| | New Ogorode Area | 5.57± 0.45 | 1.96± 0.11 | 2.81± 0.22 |
| | Amukpe | 5.04± 0.36 | 1.92± 0.18 | 1.83± 0.14 |
| **Control** | Ugbenu | 6.65± 0.66 | 2.44± 0.31 | 2.79 ± 0.29 |

### 3.2. Seasonal variation of the Particulates

The results of the seasonal variation in the concentrations of TSP, $PM_{2.5}$ and $PM_{10}$ at each sampling point are presented in Fig. 2a-c. Higher concentrations of the particulates were observed in the dry season than in the wet season across most of the sampling points. The lower concentrations during the wet season could be due to scavenging effect of the atmosphere by rainfall. When there is high rainfall, air quality is generally better due to wash-down by rain. As shown in Table 3, the seasonal average values of TSP, $PM_{2.5}$ and $PM_{10}$were consequently higher ($P<0.01$) in the dry season. This could be a result of increased combustion activities (both industrial and domestic), higher rate of re-suspended dust and less wash-down of emissions arising from traffic and gas flaring activities in the study areas. The average values obtained for both wet and dry season clearly exceeded the



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regulatory limits of FMENV of 250µg/m$^3$ (0.25mg/m$^3$) for TSP and NAAQS of 150µg/m$^3$ (0.150mg/m$^3$) and 35µg/m$^3$ (0.035mg/m$^3$) for $PM_{10}$ and $PM_{2.5}$ respectively. A similar observation was reported by Ede et al., (2010) and Gobo et al., (2012) in studies conducted in Port-Harcourt

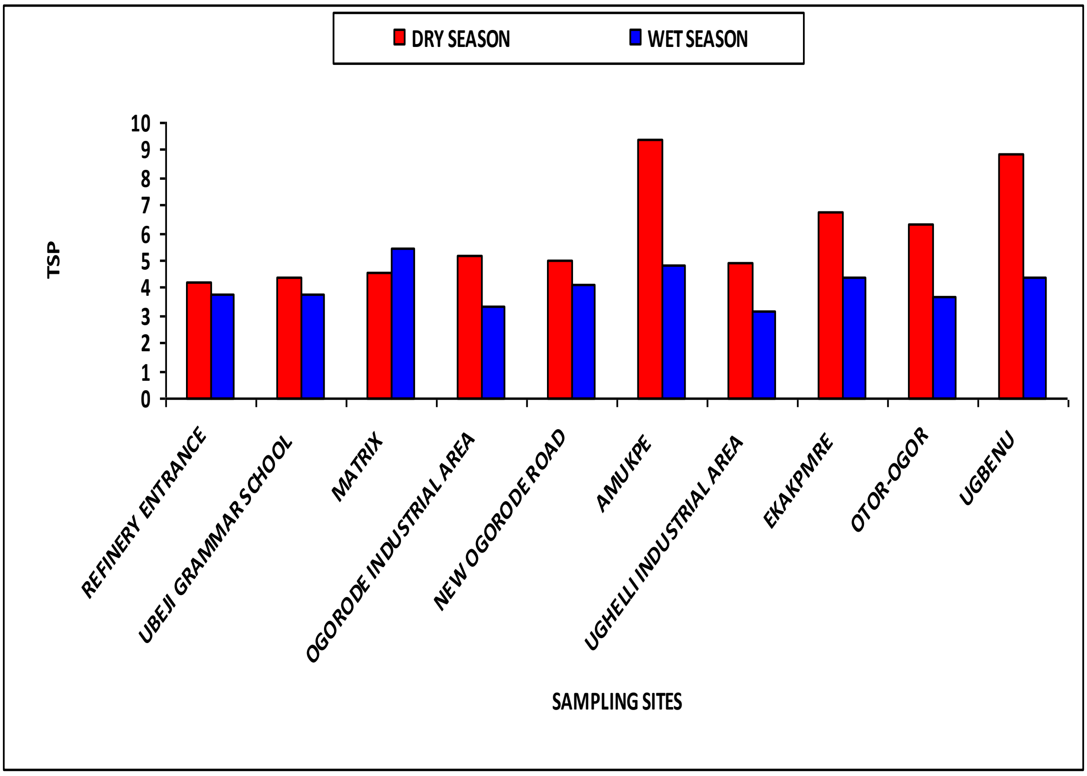


**Figure 2a: Seasonal variation of TSP levels with recommended standard. Dashed lines represent FMENV limit of 0.025 mg/m$^3$**

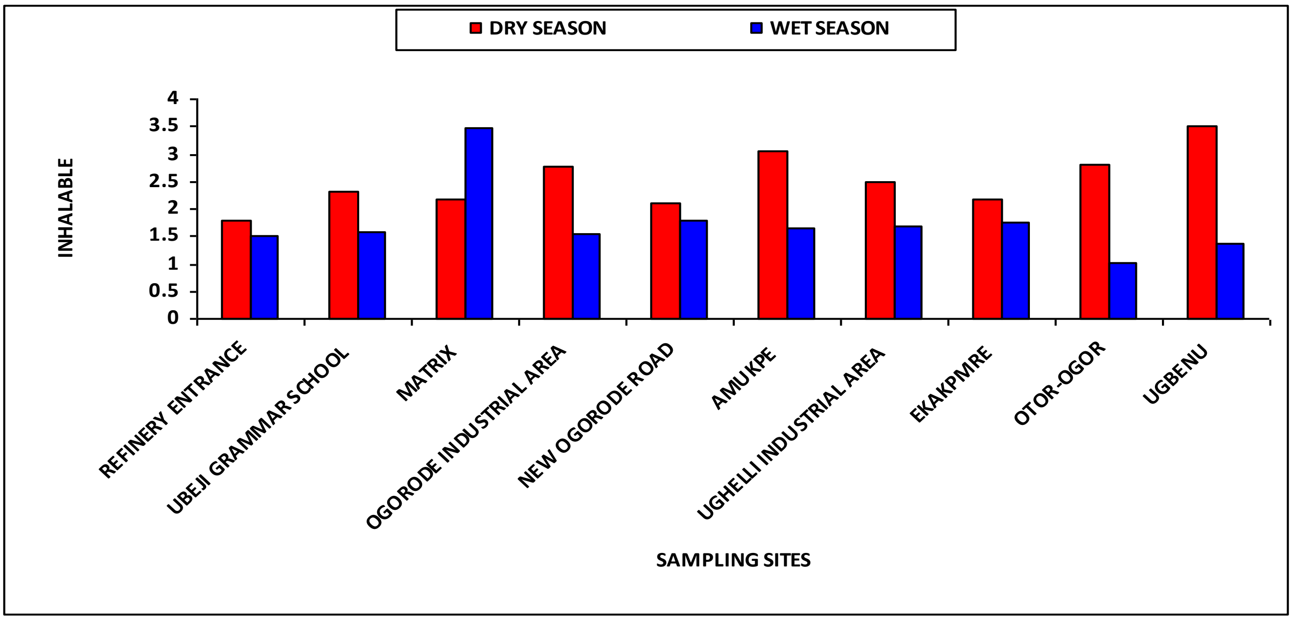


**Figure 2b: Seasonal variation ofPM$_{10}$ levels with recommended standard. Dashed lines represent NAAQS limit of (0.15mg/m$^3$)**



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**Table 3: Average seasonal values of particulates and meteorological parameters**

| Parameters | Dry Season | Wet Season | P-value |
|---|---|---|---|
| **TSP ($mg/m^3$)** | 5.97 ± 0.28 | 4.09 ± 0.23 | 0.000 |
| **Inhalable($mg/m^3$)** | 2.52 ± 0 .09 | 1.74 ± 0.20 | 0.000 |
| **Respirable($mg/m^3$)** | 2.69 ± 0.17 | 1.65 ± **0**.08 | 0.000 |
| **Windspeed (m/h)** | 0.62 ± 0.07 | 0.34 ± **0**.05 | 0.001 |
| **Temperature ($^oC$)** | 34.42 ± 0.29 | 28.68 ± 1.38 | 0.000 |
| **Light (lux** | 1146.28 ± 47.0 | 874.71 ± 63.09 | 0.001 |
| **Humidity (% RH)** | 55.59 ± 2.46 | 64.45 ± 3.47 | 0.040 |

The result of the Pearson correlation coefficient between particulates and meteorological parameters is shown in Table 4. The correlation of meteorological parameters with TSP, $PM_{10}$ and $PM_{2.5}$ shows that only temperature had a weak, but significant, correlation with TSP ($r = 0.37$, $p<0.01$), $PM_{10}$ ($r = 0.21$, $p<0.05$) and $PM_{2.5}$($r = 0.40$, $p<0.01$) while other parameters did not show any correlation with the concentration of the particulates. Similar positive correlations between temperature and $PM_{2.5}$ were reported in other studies (Wang and Ogawa, 2015; Chen et al., 2018). This can be attributed to the fact that higher temperature promotes photochemical reactions of precursors leading to the formation of particulates (Wang and Ogawa, 2015). The low correlation or absence of correlation between the particulates and meteorological parameters suggests that anthropogenic contributions are significant to their concentration in the study areas. There was a strong positive correlation between TSP and $PM_{10}$ ($r = 0.80$, $p<0.01$) and $PM_{2.5}$ ($r = 0.89$, $p<0.01$). This is expected since both $PM_{10}$ and $PM_{2.5}$ make up the large portion of TSP.

**Table 4: Correlation co-efficient of particulates concentration with meteorological parameters**

| | **TSP** | **$PM_{10}$** | **$PM_{2.5}$** | **Wind speed** | **Temp.** | **Light** | **Humidity** |
|---|---|---|---|---|---|---|---|
| **TSP** | 1 | | | | | | |
| **$PM_{10}$** | 0.80** | 1 | | | | | |
| **$PM_{2.5}$** | 0.89** | 0.52** | 1 | | | | |
| **Wind speed** | 0.01 | 0.01 | 0.04 | 1 | | | |
| **Temp.** | 0.37** | 0.21* | 0.40** | -0.45** | 1 | | |
| **Light** | 0.02 | 0.03 | 0.02 | -0.25* | 0.37** | 1 | |
| **Humidity** | -0.31** | 0.11 | 0.35** | 0.42** | 0.66** | 0.30** | 1 |

## 4. CONCLUSION

Data generated from this study showed that all the particulates (TSP, Respirable and Inhalable) measured in both seasons for all the sampling sites clearly exceeded the regulatory limits as a result of biomass combustion, bush burning, automobile emissions, generator emissions, industrial emissions and gas flaring at the sampling locations. Major pollutants being bush burning, biomass combustion, automobile emissions and dust particles from unpaved road; this explains high concentration of the particulates at Ugbenu location. This research also indicated seasonal variation with higher concentrations in the dry season than the wet season. This is as a result of increased wind movement of particulates/aerosols, scavenging effect of the atmosphere and burning of substances in the dry season. But in the wet season, particulates are dissolved due to rainfall. It can be seen that unindustrialized areas can be under serious threat associated with particulate pollution as seen in Ugbenu location.

Matrix, Otorgor and New Ogorode Area recorded the highest concentration of the particulates out of the three cities studied. Stringent regulation and compliance should be enforced to curb the pollution at the sampling locations.

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## SUPLEMENTARY INFORMATION

**Table 1: Sampling Locations, Site Descriptions and Metrological Parameters.**

| City | Sampling Location | Latitude | Longitude | Temperature ($^{o}$C) | Wind speed (m/h) | Humidity (% RH) | Light (lux) | Site Description |
|---|---|---|---|---|---|---|---|---|
| **Warri** | Refinery Entrance | N05$^{0}$ 34'10" | E005$^{0}$ 42'13.8" | 32.24± 0.506 | 0.490 ±0.185 | 74.54±3.338 | 4,964.1±2182.41 | This location is outside Warri refinery. |
| | Ubeji Grammar School | N05$^{0}$ 34'19.6" | E005$^{0}$ 42'13.8" | 34.17±1.048 | 0.51±0.247 | 66.81±6.710 | 5,516.9±954.73 | This location is School Environment |
| | Matrix | N05$^{0}$ 32'11.6" | E005$^{0}$ 41'11.3" | 33.49±0.448 | 0.37±0.126 | 70.01±5.013 | 1,136.15±154.95 | Concentration of Tank Farms |



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| **Ughelli** | Ughelli Industrial Area | N05$^{0}$ 32'28.1" | E005$^{0}$ 55'10.2" | 30.98±0.603 | 0.48±0.106 | 70.24±3.649 | 1,169.8±1106.91 | Highly industrialized area. |
| | Ekakpamre | N05$^{0}$ 31'15.9" | E005$^{0}$ 54'20.3" | 33.81±0.459 | 0.72±0.218 | 61.05±1.615 | 7,697.9±1317.33 | Residential and business area. |
| | Otorgor | N05$^{0}$ 27'31.8" | E006$^{0}$ 01'21.0" | 35.11±0.457 | 0.19±0.086 | 67.42±4.620 | 6,147.2±565.34 | Outskirt of Ughelli |
| **Sapele** | Ogorode Industrial Area | N05$^{0}$ 55'17.3" | E005$^{0}$ 38'47.8" | 31.62±0.427 | 0.36±0.126 | 70.24±4.859 | 1,119±647.03 | Highly Industrialized area. |
| | New Ogorode Area | N05$^{0}$ 53'14.3" | E005$^{0}$ 40'00.5" | 33.1±0.711 | 0.36±0.170 | 53.86±5.593 | 1,036.3±62.89 | Residential and business area. |
| | Amukpe | N05$^{0}$ 51'16" | E005$^{0}$ 43'13" | 33.18±0.691 | 0.74±0.167 | 50.6±3.393 | 1,182.4±684.30 | Market area with heavy traffic. |
| **Control** | Ugbenu | N06$^{0}$ 01'50." | E005$^{0}$ 40'22.6" | 33.76±0.608 | 0.47±0.169 | 59.08±4.176 | 3,545.5±97.59 | Residential area, devoid of industrial activity. |



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