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Research Paper

Evaluation of Ambient Air Quality in Obrikom and Omoku Communities in Rivers State Nigeria

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ABSTRACT
Air quality and meteorological parameters in Omoku. Obrikom and Elele-Alimini (control) communities in Rivers State were monitored in the morning, afternoon and evening once in every month for twelve months across eight locations. Gaseous pollutants and particulate matter were determined in-situ using digital hand-held gas monitors with electrochemical sensors. The results showed that wind direction alternated between South West (SW) and South East (SE) in the wet season and between South West (SW), South East (SE) and North East (NE) in the dry season. Relative humidity correlated negatively with temperature (r = -0.786) and heat radiation (r = -0.545). Air Quality Index was poor especially in the months of September – January reaching maximum values for NO_2 (68), SO_2 (612), CO (138), $PM_{2.5}$ (165) and PM_{10} (137). The concentrations of SO_2, CO, $PM_{2.5}$ and PM_{10} exceeded WHO, USEPA and NESREA recommended limits especially at station 3. However, VOC, CO_2, CH_4 and H_2S concentrations were below toxic levels at all stations throughout the year. VOC correlated significantly with PM_{10} and moderately with CH_4, CO, H_2S, NH_3 and Cd. PM_{10} correlated with H_2S and NH_3. The study concluded that the communities were exposed to moderate to high concentrations of gaseous and particulate matter pollutants which may adversely affect the health of the people under prolonged exposure. The air quality at station 3 was also poor, especially in the dry season. The control station (station 8) generally showed significantly ($p<0.5$) lower levels of gaseous pollutants and particulates than the study stations. The study therefore recommended that the air quality in the area should be regularly monitored and Gas flaring by oil industries and other practices by the residents should be minimized. Health impact assessment should also be conducted regularly in the communities to determine the level of impacts of the pollutants.

KEYWORDS: *Air quality, pollutants, particulate matter, Gases, Obrikom, Omoku*

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I. INTRODUCTION

The term pollution is now one of the prevalent expressions used concerning the environment in Rivers States of Nigeria resulting from the several human activities in the area. Vallero (2008) defined air pollution as "the presence of contaminants or pollutant substances in the air that interfere with human health or welfare, or produce other harmful environmental effects". Air quality and air pollution study is however complex, due to the multitude and extreme variability of the pollutants, their sources, classification and impacts.

Although human activities are identified as the major source of air pollution, natural sources of air pollution exist. The natural sources of air pollution arise from natural processes such as forest fires, tornados, volcanic eruptions, pollen dispersal etc.

Irrespective of air pollution sources and classification, their impact on man and the environment is a major issue of concern. These impacts are pronounced in their dispersion, travel distance, particle size, transformations and final effect. According to the WHO, air pollution constitutes the largest health risk among all environmental risks and 92% of the world's population breathes substandard air as they live in places where air pollution exceeds safe limits. WHO attributed annual deaths around the world resulting from poor air quality inside and outside as about 6.5 million, making air pollution the world's fourth-largest threat to human health, behind high blood pressure, dietary risks and smoking. It has also been showed that air pollutant with small

particle size (decreased diameter), are able to infiltrate finer lung structures and cause severe health effects such as asthma (WHO, 2006), chronic obstructive pulmonary disease (COPD) or increased cardiovascular risks (Gauderman *et al.* 2007 and Hoffmann et al. 2007). Other air pollution effects include the development of upper airways diseases such as sinusitis, mild otitis, olfactory impairment, rhinitis and sinonasal cancer (Shusterman, 2011).

Since air pollution and deteriorating air quality are mostly attributed to human activities, most countries have strengthened laws to control air pollution and safe limits for air quality in the past decade to reduce its impact on man and the environment. The Constitution of the Federal Republic of Nigeria, established the fundamental idea of environmental policy in the country making it mandatory for the Nigerian State to enforce the protection of air, land, and water, as well as ecosystems, including forests and wildlife (Constitution of the Federal Republic of Nigeria 1999).

Ideriah *et al*., (2020) reported that welding workshops contribute significant concentrations of air pollutants and pose health risk to welders and residents alike. Studies have shown that levels of air pollutants indoors are higher than outdoors (Gobo *et al*. 2009, Nwogbidi et al., 2019) and dry season concentrations are higher than rainy season concentrations (Gobo *et al* , 2012, Antai *et al.*, 2020, Ubong *et al*., 2015 Okonkwo *et al*., 2014). High SPM loads were associated with factors such as high numbers of oil fields and gas flare sources, construction activities, and hamattan (Ede and Edokpa, 2015, Ubong *et al*., 2015). Ideriah *et al*., (2001) reported that SPM concentrations at indoor night were higher than indoor day and outdoor day concentrations. Also SPM levels in the rural communities were higher than those in the urban communities. De Freitas *et al*. (2018) in a review of wind speed forecasting proposed that consistent wind speed forecasts are relevant and must be prepared to avoid economic losses, facilitate regulation of wind systems, and increase the operational efficiency of industries through a more reliable decision making.

Based on WHO statistics of 2006, air pollution constitutes the largest health risk among all environmental risks and 92% of the world's population breathes substandard air (WHO, 2006).

Six million five hundred thousand annual deaths around the world have been attributed to poor air quality and this has made air pollution the world's fourth-largest threat to human health, behind high blood pressure, dietary risks and smoking (WHO, 2006). Despite this statistics from WHO there is limited information on air quality and the human health risk associated with air pollutants in the study area. There is absence of observatory stations for air emissions and air quality monitoring. These monitoring stations if available will provide real time weighted data and information on air pollution if any, and lengths of exposure at which specific adverse effects on health and welfare may occur.

Therefore, it is necessary to carry out this study to quantify the air pollutants (gaseous, organics and heavy metals) in the study area and provide information on the air quality of the area. Also, this study shall assess the human health risk associated with heavy metals in air in the study area. It will also serve as a useful reference material and catalyst to stimulate future researches. It will further create awareness amongst inhabitants to adopt mitigation measures to avoid or reduce exposure to air pollution sources. The aim of this study is to quantify the gaseous and particulate air pollutants in the study communities in Rivers State.

II. MATERIALS AND METHODS

Description of the Study Area

Omoku and Obrikom Towns are located approximately on latitude 4° 51' 29.16" N longitude 6° 55' 15.24" E, and on latitude 4° 51' 29.16" N longitude 6° 55' 15.24" E, while Elele Alimini is located on latitude 4° 51' 29.16" N longitude 6° 55' 15.24" E. They are all situated in Rivers State, southern Nigeria in the core of the Niger Delta region which covers an area of about 21,110 square kilometers (NDDC, 2004).

The study area is basically a huge floodplain formed primarily by centuries of silt washed down by the Niger and Benue Rivers. It is crisscrossed by a web of creeks that link together the main rivers of Benin, Bonny, Brass, Forcados, Nun, and other rivulets and streams (all estuaries of the Great River Niger). It has a rich and diverse variety of ecological types with several mangrove and freshwater swamp forest that accommodates very high biodiversity, with many unique species of plants and animals.

The meteorological conditions of the study area display climatic characteristics that could be classified as semi-hot equatorial zone. The equatorial maritime air mass characterizes the climate with high humidity and heavy rainfalls (annual mean ranges between 72% -81% and 3,000mm-4,000mm). Specifically, these climatic characteristics range from the hot equatorial forest type in the southern lowlands to the humid tropical in the northern highlands. The wet season is relatively long, lasting between seven and eight months of the year, from the months of March to October (considered as rainy season). There is usually a short break around August, otherwise termed the "August break". The dry season begins in late November and extends to February or early March, a period of approximately three months although; the atmosphere sustains adequate moisture throughout the year. (Gobo & Abam, 1991).

The climatic characteristics are governed by the general circulatory patterns of two air masses: the dry dusty North-East Trade wind (Tropical continental air masses) from the Sahara Desert which come in the dry season (October - March), bringing in the harmattan from December – January and the moisture laden south-west wind (tropical maritime air masses) which bring rain during the wet season (April - October).

The meteorological analysis of the prevailing wind patterns in the study area revealed that the wind direction persists from the southwest for most of the year (Ojo, 1977). Temperatures are generally high in the region and fairly constant throughout the year. Average monthly maximum and minimum temperatures vary from 28^{o}C to 33^{o}C and 21^{o}C to 23^{o}C, respectively, increasing northward and westward with the warmest months being February, March and early April. The coolest months are June through to September during the peak of the wet season.

Geographically and topographically the study area is such that air borne pollutants travel fast and the farthest, as high lands are practically absent. Furthermore, occurrence of land breeze, as well as harmatan, facilitates emission transfer into the study area (NDDC, 2004).

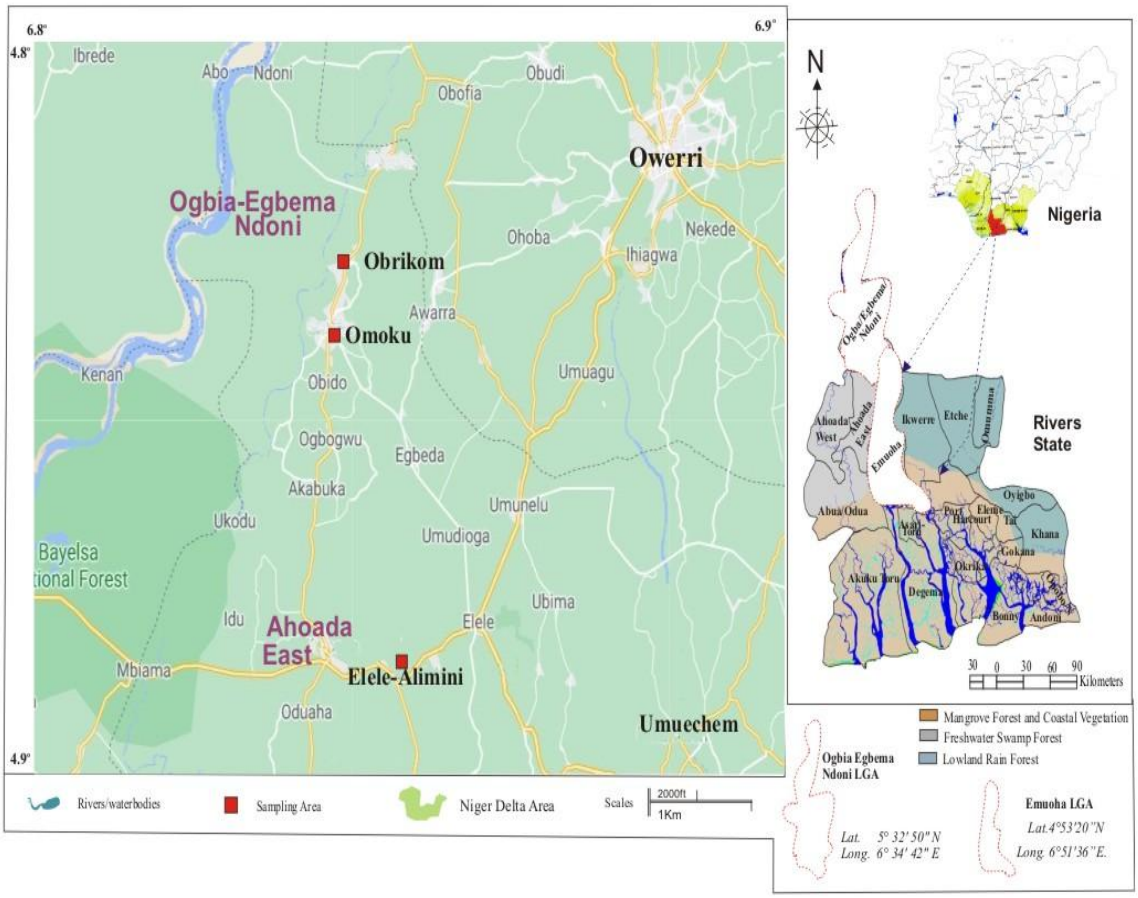

Fig 1: Map of the Study Area showing the sampling locations

Sampling Frequency

Air quality and meteorological parameters shall be carried out Morning (5:00am – 11:00am), Afternoon (12:00 noon – 4:00 pm) and Evening (5:00 pm – 11:00 pm) once in every month for twelve (12) months (April 2019 to March, 2020). Morning, afternoon and evening are represented as M, A and E respectively.

Sampling and analysis of heavy metals shall be carried out three times a day, Morning (5:00am – 11:00am), Afternoon (12:00 noon – 4:00 pm) and Evening (5:00 pm – 11:00 pm) once in every month for twelve (12) months (April 2019 to March, 2020).

Sampling and analysis of Organics shall be carried out three times a day Morning (5:00am – 11:00am), Afternoon (12:00 noon – 4:00 pm) and Evening (5:00 pm – 11:00 pm) once in every month for twelve (12) months (April 2019 to March, 2020).

Analytical Method Description

(a) Wind Speed and Direction

The wind speed shall be determined using kestrel weather tracker anemometer. The anemometer read wind speed in meters per second (m/s). The direction of the wind is noted with an in-built wind vane and compass.

(b) Relative Humidity

Humidity will be measured with Kestrel weather tracker (hygrometer) with a range of 0-100%.

(c) Sun Radiation

A UVX Digital Radiometer (UVXE29238) shall be used to measure the Sun radiation.

(d) Smoke Density

A graduated Ringelmann chart (BS 2742M) shall be used to determine the smoke density of the flares in any sampling point that is near a point source of air pollution.

The chart is numbered from 0-4 with 0 being the lowest density, while 4 is the highest. The chart shall be held high, at about 20 meters away from the smoke emanating from the point source and percentage light intensity is compared with the chart.

(e) Particulates (SPM, $PM_{2.5}$, PM_7, PM_{10})

ISO 14644/ EPA 1O-2 shall be employed for the Airborne Suspended Particulate Matter ($PM_{2.5}$, and PM_{10}) determination using Kanomax 3900 Portable Counter High Volume Sampler sampler (Andover, USA) and HoldPeak particle counter (Zhuahai, China). Kanomax 3900 Portable Counter High Volume Sampler (Andover, USA) provides both real-time as well as gravimetric dust concentration with a sampling range of 0.001mg/m^3 to 250g/m^3. The sampling unit consists of a graphic display device attached to a probe. The probe works based on forward light scattering principles. Diffusion air passes through an inlet in the probe and particulate matter present in the air sample scatters a modulated laser light in the probe inlet. The amount of scattering is correlated to the concentration of particulate matter present which is displayed on the screen. Kanomax 3900 particle counter high volume sampler pump air at a rate of 28.3 $Lmin^{-1}$. For the determination of the fine and coarse particulates, EPM 2000 membrane filters shall be inserted in the instruments' probe to ensure the accurate quantification of the dust sizes respectively.

(f) Gases (CO, NO_2, SO_2, H_2S, NH_3 and VOCs)

Concentrations of the above gases shall be determined using an Aeroqual 500 Series air quality sensor. Aeroqual Series 500 uses electrochemical sensors for analysis of the toxic gases with the removable sensor heads for each of the gas. The sensor heads feature active sampling which ensures that a representative sample is taken giving very reasonable accuracy. It has a sampling range of 0-1000, 0-1, 0-100, 0-10, 0 - 1000 and 0-1000 ppm respectively for CO, NO_2, SO_2, H_2S, VOCs and NH_3. The corresponding minimum detection limits respectively are 1, 0.005, 0.4, 0.04, 0.01 and 2. The results shall be calculated in accordance to ASTM D1914 – 2005.

III. RESULTS AND DISCUSSIONS

The result from Tables 1 and 2 and Figs. 2-6 showed that the ambient temperature values at the study area ranged from 22.4^{o}C to 33.2^{o}C at station 7 with a mean of 27.5 ±0.2^{o}C in the wet season and from 26.3^{o}C at station 1 to 38.2^{o}C at station 7 with a mean of 32.2 ± 0.3^{o}C in the dry season. Atmospheric temperature is higher during the dry season (November to February) than during the raining season (March to October). Furthermore, monthly temperature trends showed a continuous variability which is dependent on the season. It revealed that the highest mean temperature levels were recorded in November. This is because November is characterized by very little amount of precipitation and lots of sunshine. Typically, in November, as well as in other months during the dry season, evaporation exceeds precipitation, leading to increased aridity and high temperatures (Uko & Tamunobereton-ari, 2013). Monthly variations in temperature levels showed significant difference ($p<0.05$), while variations between the stations were not significantly different ($p>0.05$).

Although the study area features an equatorial monsoon climate- as is typical of the coastal region of Southern Nigeria- slight increases in temperature in the dry season may also be attributed to tropical continental air mass which blows southwards from the Northern Sahara Desert into Nigeria (Yusuf, *et.al*., 2017). A hot atmosphere with high relative humidity may cause slow cooling of human body due to the reduced rate of evaporation from the skin, thus making human body to feel hotter than the actual surface temperature (Salau, 2016). This may result in increased internal heat, disruption of the functioning of enzymes, heat stroke and rise in mortality during heat waves (Salau, 2016).

Wind roses indicating speed and direction at stations 3 and 5 are presented in Figs. 7-10. Wind speed ranged from 0.1m/s at station 4 to 2.0m/s at station 2 with a mean value of 0.9 ± 0.0m/s in the wet season and from 0.3m/s at stations 4 and 8 to 2.0m/s at station 6 with a mean value of 1.0±0.0m/s in the dry season. Monthly variations of wind speed showed significant difference ($p<0.05$) with October having the highest wind

speed level in a year. Variations in wind speed between the stations were not significantly different ($p>0.05$). Wind speed which is a measure of air ventilation has a direct effect on outdoor thermal comfort. It has however been shown that the morphology of urban areas as well as building coverage significantly degrades air ventilation (Nichol &Wong, 2009). Other beneficial aspect of the measurement of wind speed include wind forecasting which is used in the planning for the construction of wind farms (De Freitas, *et.al*., 2018). The wind pattern over an area is also essential in the determination of pollutant transport (Akinyemi, *et.al*., 2016). In this study, the wind direction alternated between South West (SW) and South East (SE) in the wet season and between South West (SW), South East (SE), North West (NW) and North East (NE) in the dry season.

The results from this study showed lower wind speed values when compared with Oyewole and Aro (2018) in their measurement of Wind Speed pattern in Nigeria. They found the aggregate mean wind speed in Port Harcourt to be 5.51 m/s which is much higher than the 0.9 m/s aggregate mean wind speed found in this study. This implies that pollutants in the study area are not widely dispersed and this can portend danger of persistence of the pollutants.

The relative humidity values ranged from 40.1% at station 6 to 84.5% at station 8 with a mean of 74.3±0.5% in the wet season; 26.0% at station 1 and 5 to 79.4% at station 1 with a mean of 57.3±1.2% in the dry season. The levels of relative humidity during the wet season were generally higher than in the dry season. Monthly variations of relative humidity were significantly different ($p<0.05$), while variations from station to station were not significantly different ($p>0.05$).

Relative humidity represents a percentage of water vapor in the air that changes with air temperature. The observed variation in the levels of relative humidity between the wet and dry seasons can be attributed to the difference in the amount of moisture in the air as well as air temperature between the two seasons. Generally, when it rains, it can have a considerable impact on the humidity in the air (Mawonike & Mandonga, 2017). It may cause too much humidity, thus adding too much moisture into the air. On the other hand, as air temperature increases, air can hold more water molecules, and its relative humidity decreases. When temperatures drop, relative humidity increases (Mawonike & Mandonga, 2017). The correlation coefficient (r) between temperature and relative humidity in this study was -0.786 showing very high negative correlation between relative humidity and temperature, thereby agreeing with previous studies.

Temperature and humidity affect people's comfort levels as well as their health (Dotson, 2018). In general, relative humidity below 25% feel uncomfortably dry, while relative humidity above 60% feel uncomfortably humid (Brennan, 2018). Flu and infuenza viruses tend to thrive when outdoor temperatures grow colder. Research indicates aerosolized influenza virus is more stable at lower relative humidity (Lowen & Steel, 2014; Yang, et.al., 2012). At the study area, the risk of infection of flu is higher during the dry season due to low relative humidity during this period.

The heat radiation values ranged from 22.0W/m^2 at station 2 and 6 to 65.2W/m^2 at station 2 with a mean of 33.8 ± 0.6W/m^2 in the wet season; 25.4W/m^2 at station 2 and 6 to 66.9W/m^2 at station 2 and 6 with a mean of 35.9 ± 0.2W/m^2 in the dry season. Monthly variations in Heat radiation were significantly different ($p<0.05$), while station level variations were not significantly different ($p>0.05$). Radiation processes in the atmosphere play a major role in the energy and radiation balance of the earth-atmosphere system (Harde, 2013). Many factors such as emission of greenhouse gas and loss of urban tree cover can however distort the natural mechanism that ensures the balance of heat radiation in the atmosphere, thus leading to global warming (Nwaerema & Weli, 2018).

It was observed in this study that there was a high negative correlation between relative humidity and heat radiation ($r = -0.545$) (table 4.6.23). Reports from other studies have shown that global solar radiation increases with decrease in relative humidity (Abdullahi *et al*., 2017). Also, Ruosteenoja and Räisänen (2013) reported that changes in RH and solar radiation correlate negatively in their study of seasonal changes in solar radiation and relative humidity in Europe in response to global warming.

The wet season atmospheric pressure values ranged from 1000.3mmHg at station 8 to 1008.9mmHg at station 3 with a mean of 1004.7±0.1mmHg and the dry season values ranged from 1000.9mmHg at station 1 and 5 to 1009.0mmHg at station 2 and 6 with a mean of 1004.6±0.2mmHg. An annual mean atmospheric pressure value of 1004.7±0.1 mmHg was recorded. April recorded the highest atmospheric pressure level of 1005.7 mmHg, while October was the only month with a statistically significant ($p<0.05$) lower atmospheric pressure level than the rest. Station level atmospheric pressure mean values show a significant difference ($p<0.05$) at station 8.

Table 1: Wet and Dry Seasons Levels of Meteorological Parameters Measured at the Study Area

	WET SEASON				DRY SEASON			
Parameter	**Min**	**Max**	**Mean**	**SEM**	**Min**	**Max**	**Mean**	**SEM**

;								
Atm.Temp. (^{O}C)	22.4	33.2	27.5	0.2	26.3	38.2	32.2	0.3
Wind Speed (m/s)	0.1	2.0	0.9	0.0	0.3	2.0	1.0	0.0
Rel. Humidity (%)	40.1	84.5	74.3	0.5	26.0	79.4	57.3	1.2
Heat Radiation (W/m^2)	25.0	66.9	35.9	0.6	25.0	66.9	35.9	0.6
Atm.Press (mmHg)	1000.3	1008.9	1004.7	0.1	1000.9	1009.0	1004.6	0.2

Table 2: Annual Levels of Meteorological Parameters Measured in the Study Area

ANNUAL VALUES				
Parameter	**Min**	**Max**	**Mean**	**SEM**
Atm.Temp. (^{O}C)	22.4	38.2	29.5	0.2
Wind Speed (m/s)	0.1	2.0	0.9	0.0
Rel. Humidity (%)	26.0	84.5	67.2	0.8
Heat Radiation (W/m^2)	22.0	66.9	32.1	0.4
Atm.Press (mmHg)	1000.3	1009.0	1004.7	0.1

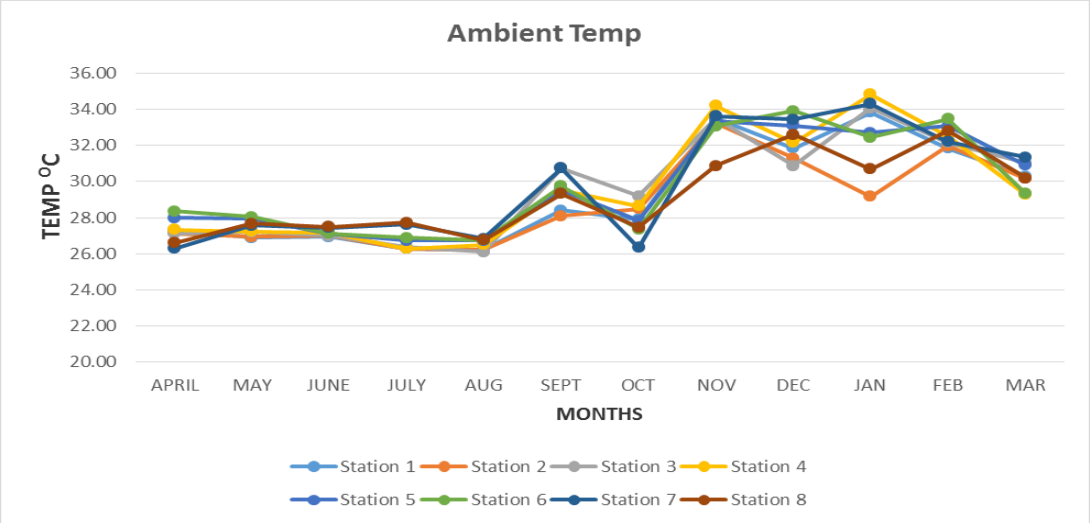

Fig 2: Monthly Variations in Ambient Temperature at the Study Area

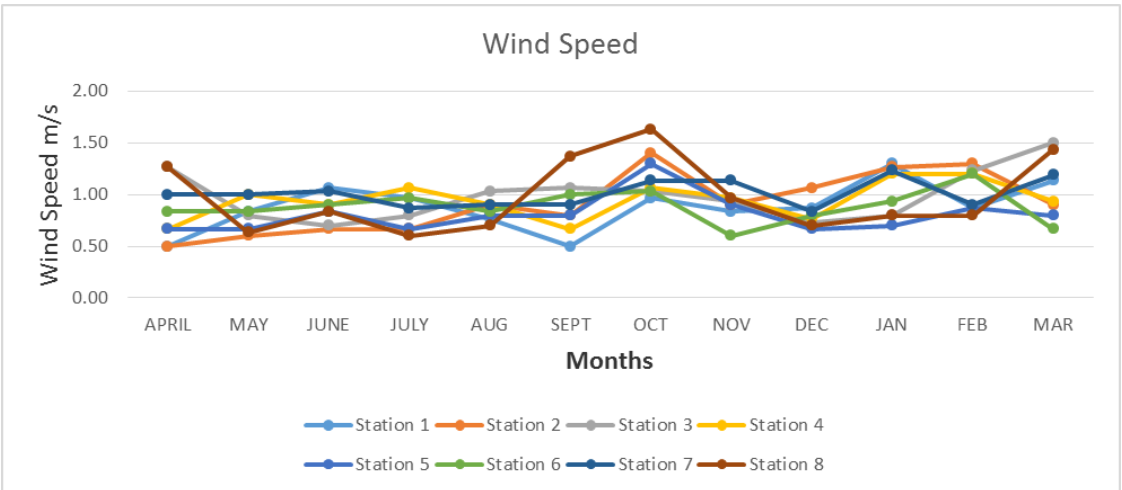

Fig 3: Monthly Variations in Wind Speed at the Study Area

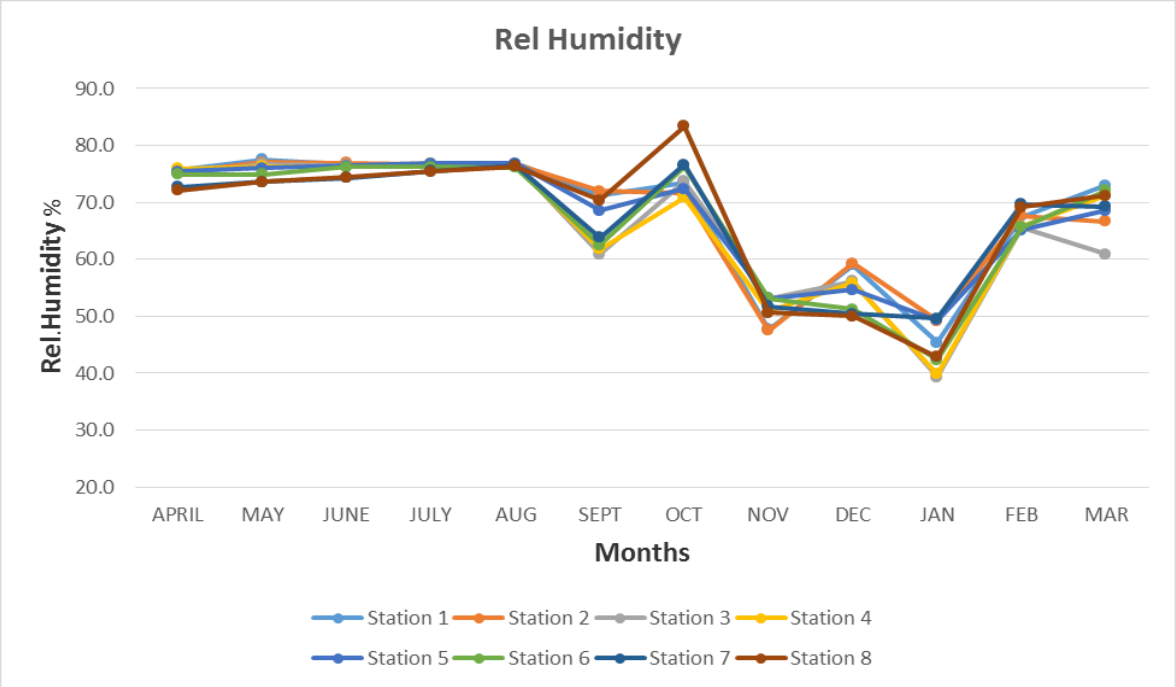

Fig 4: Monthly Variations in Rel. Humidity at the Study Area

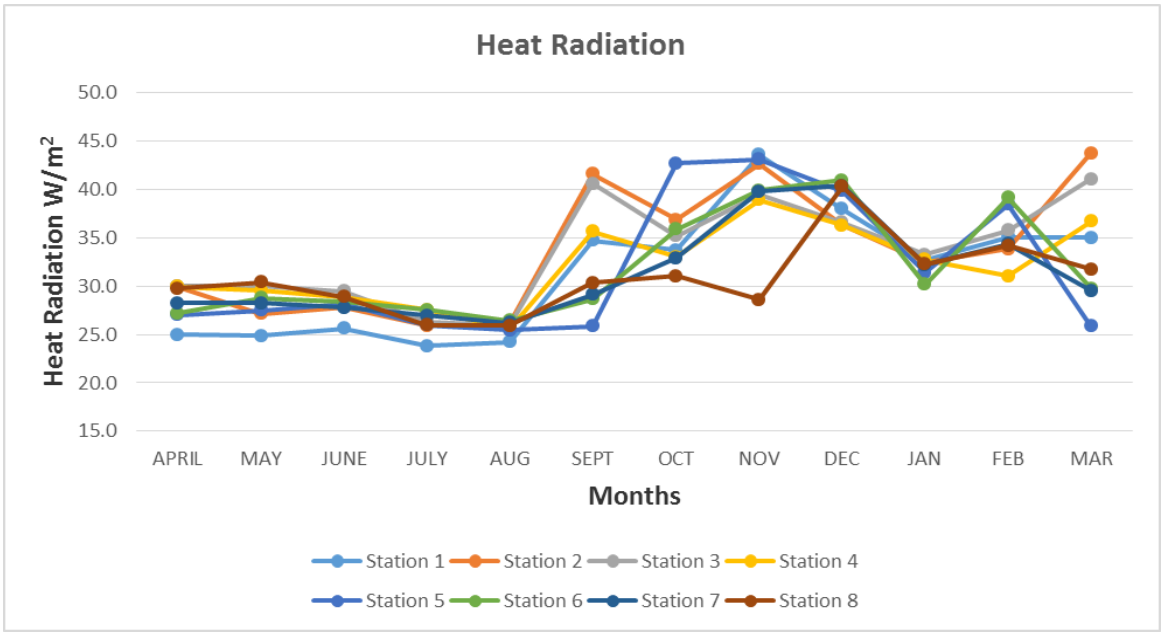

Fig 5: Monthly Variations in Heat Radiation Measured at the Study Area

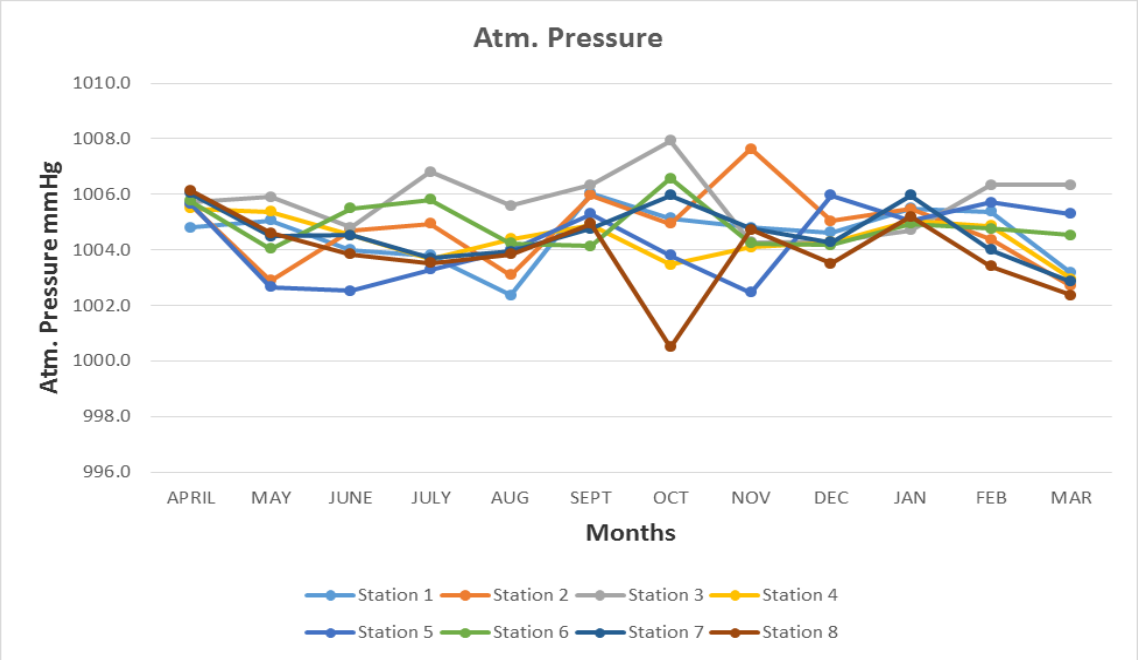

Fig 6: Monthly Variations in Atm. Pressure Measured at the Study Area

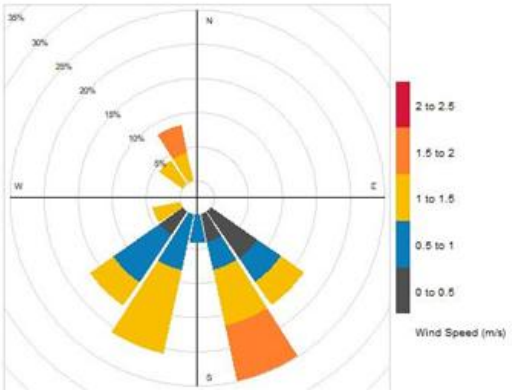

Fig 7: Wet Season Wind Direction for Station 3

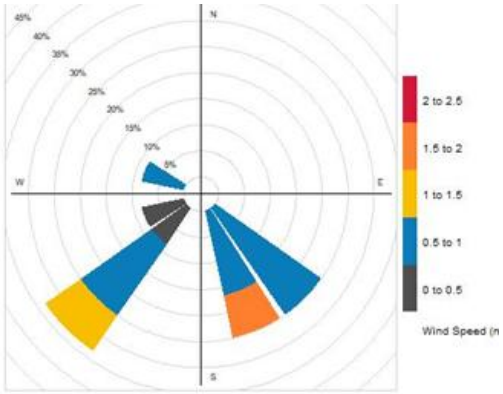

Fig 8: Dry Season Wind Direction for Station 3

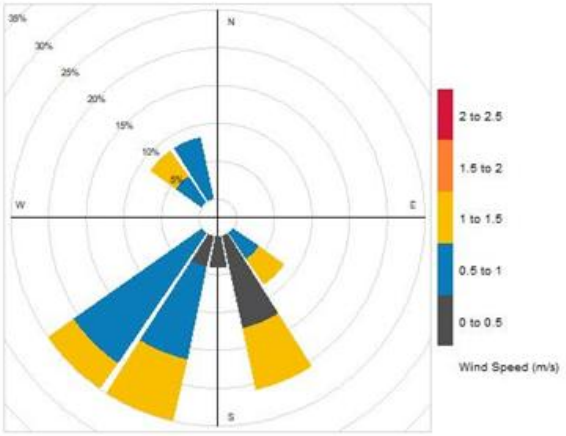

Fig 9: Wet Season Wind Direction for Station 5

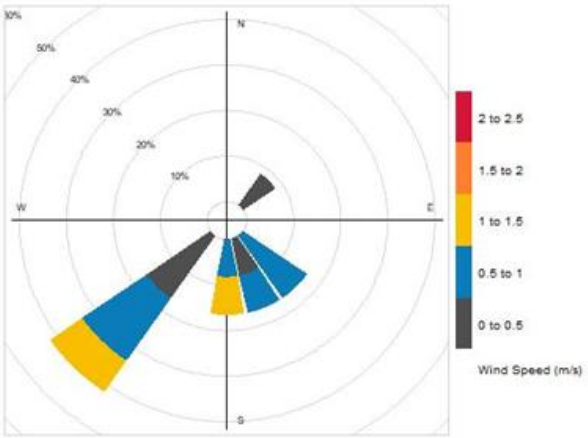

Fig 10: Dry Season Wind Direction for Station 5

The results of gaseous and particulate matter from the study areas are shown in Tables 3 and 4 and Figs. 11-20 while pollution roses from PM_{10} at station 3 and $PM_{2.5}$ at station 5 are shown in Figs. 21-24. The NO_2 concentrations at the study area ranged from 0.002ppm at station 8 to 0.077ppm at station 1 with a mean of 0.020±0.001ppm in the wet season; 0.003 ppm at station 4 to 0.058 ppm at station 8 with a mean of 0.029

±0.002ppm in the dry season. The annual mean NO_2 concentration at the study area was 0.024 ±0.001ppm. In general, dry season levels of NO_2 were higher than wet season levels. The month of January recorded the highest mean concentration of NO_2 (0.044 ppm) while July recorded the least (0.013 ppm). Monthly variations in NO_2 concentration were significantly different ($p<0.05$), with the months of January and February recording significantly higher values than all the other months. Variations resulting from the mean concentration of NO_2 at the different stations also showed significant difference ($p<0.05$), with station 3 having significantly higher concentration of NO_2 than stations 4, 6 and 7. Statistically significant lower concentrations of NO_2 was recorded at the control station (station 8) compared to all other stations.

Air quality index for NO_2 at the study stations showed mostly good and moderate pollution levels with the poorest AQI index of 68.0 recorded in February at station 1. The dry and wet season levels of NO_2 at the study area fall within the limits 200 µg/m^3 (0.106 ppm), 100 ppb (0.1 ppm) and 200 µg/m^3 (0.106 ppm) respectively recommended by WHO (2018), USEPA (2020) and NESREA (2014). The levels of NO_2 in this study were also found to be below levels of up to 1ppm reported by Antai *et al*. (2020) in their assessment of air quality in Eleme, Rivers State, Nigeria. The primary source of NO_2 in air is from the combustion of fuel in cars, trucks, buses and power plants (Liu *et al*., 2020). The low levels of NO_2 observed in this study compared to the study in Eleme might be because of less vehicular presence in the study area.

VOC concentrations ranged from 1.00ppm to 6.90ppm at station 3 with a mean of 2.05 ±0.09ppm in the wet season; 0.01ppm at stations 1,4,6 and 8 to 12.8ppm at station 3 with a mean of 3.23 ±0.26ppm in the dry season. The annual mean VOC concentration at the study area was 2.54 ±0.13ppm. VOC concentrations during the dry season were generally higher than in the wet season. Both monthly and station levels variations of VOC showed significant difference ($p<0.05$). Tukey method grouping information of the concentrations of VOC recorded monthly revealed that the month of January had significantly higher value than the other months. VOC concentration was also significantly higher in February and December than in April – October, while March has significantly lower levels of VOC than all other months. At the station level, station 3 showed a significantly higher ($p<0.05$) levels of VOC than all other stations. VOC concentration was significantly lower ($p<0.05$) at the control station (Station 8) than in station 3 and 5, while it did not show any significant difference ($p>0.05$) with others.

VOC concentrations in this study were similar to values reported by Gobo *et al*., (2012) in their assessment of air quality around Okrika Communities, Rivers State, Nigeria. Volatile organic compounds (VOCs) include a variety of chemicals, some of which may have short- and long-term adverse health effects (USEPA, 2017). Exposure limits recommended by OSHA to the different components of VOCs ranged from 1 ppm (for benzene) to 500 ppm (for naphtha) (Lerner *et al.*, 2012). Level of VOCs recorded at the study area at both the wet and dry season were found to be below the recommended limits and therefore are not a source of concern in these areas.

SO_2 concentrations ranged from 0.01ppm to 1.42ppm at station 3 with a mean of 0.05 ±0.01ppm in the wet season and from 0.01ppm to 1.15ppm at station 3 with a mean of 0.07±0.01ppm in the dry season. The annual mean SO_2 concentration at the study area was 0.06 ±0.01ppm. SO_2 concentration did not show much variation between wet and dry seasons. However, both monthly and station level variations of SO_2 showed significant difference ($p<0.05$). Tukey method grouping information of the concentrations of SO_2 recorded monthly revealed significantly higher ($p<0.05$) values of SO_2 in September compared to the months of April-August, December and March. January had significantly higher ($p<0.05$) levels of SO_2 than April and August, while other grouping information by months showed no significant difference ($p>0.05$). At the stations, Tukey method of grouping information reveal that station 3 recorded significantly higher values of SO_2 than all other stations. However, the concentration of SO_2 at the control station (station 8) is not significantly different from other stations.

The air quality index for SO_2 ranged from good to moderate in all the stations except at station 3 which ranged from moderate levels between March-June and August to hazardous levels in September. Levels of SO_2 in both wet and dry seasons at the study areas were above the recommended limits of 75 ppb (0.075 ppm) and 125 µg/m^3 (0.048 ppm) by USEPA (2020) and EEA (2008). However, the NESREA (2014) recommended limits of 0.13 ppm respectively were exceeded only at station 3 in the wet season, and at all stations except stations 4, 7 and 8 in the dry season. High levels of SO_2 observed at the study area may have come from burning of fossil fuel in the study area. The release of sulphur dioxide into the atmosphere results in the formation of acid rain according to the following reactions:

$SO_2 + OH\cdot \rightarrow HOSO_2\cdot$

$HOSO_2\cdot + O_2 \rightarrow HO_2\cdot + SO_3$

$SO_3\ (g) + H_2O\ (l) \rightarrow H_2SO_4\ (aq)$

Direct impact of Sulphur has been reported and is responsible for a variety of respiratory problems (Jain *et al*., 2016). Like most air pollutants, sulfur dioxide poses a greater threat to vulnerable groups such as the

elderly, asthmatics, and young children. By contributing to acid rain, sulfur dioxide can have significant impacts on plants, surface waters, and buildings in the study area (Jain *et al*., 2016).

The cconcentrations of CH_4 ranged from 0.1ppm to 5.0ppm at station 3 with a mean of 0.4 ±0.1ppm in the wet season; 0.1ppm to 8.0ppm at station 3 with a mean of 0.9 ±0.1ppm in the dry season. The annual mean CH_4 concentration at the study area was 0.6 ±0.1ppm. CH_4 concentrations were generally higher in the dry season than in the wet season. Analysis of variance for concentration of CH_4 in the study area reveals that both monthly and station variations in CH_4 levels show significant difference at $p<0.05$. Grouping information by months using Tukey method showed that concentration of CH_4 in the months of March, September and December were significantly higher ($p<0.05$) than from June to August, while concentrations of CH_4 recorded in April and May were significantly lower ($p<0.05$) than the concentration recorded in September and December. Station variations using Tukey method showed that levels of CH_4 at station 3 were significantly different from other stations and the control station. The concentrations of CH_4 from this study were higher than the 0.20 ppm – 3 ppm (dry season) and 0.00 – 2.7 (wet season) values measured around Okrika communities in Gobo *et al*., (2012). Methane is released to the atmosphere either by natural processes like the breakdown or decay of organic material or through human activities like burning or during the exploration and transport of fossil fuels (Heilig, 1994). Little information is available on the toxicity of methane; however, the Committee on Toxicology recommends 5000 ppm exposure limit for 24 hours (Committee on Toxicology, 2000). However, methane is a greenhouse gas that contributes considerably to global warming, accounting for about 10% of all U.S. greenhouse gas emissions from human activities in 2018 (Hockstad & Hanel, 2018). Therefore, increasing amount of CH_4 in the atmosphere over time may lead to increased warming of the atmosphere.

The cconcentrations of H_2S ranged from 0.01ppm to 0.50ppm at station 3 with a mean of 0.03 ±0.01ppm in the wet season; <0.01ppm at station 3 to 0.55ppm at station 3 with a mean of 0.07 ±0.01ppm in the dry season. The annual mean H_2S concentration at the study area was 0.05 ±0.01ppm. The concentrations of H_2S observed were lower in the wet season than in the dry season. Significantly higher ($p<0.05$) mean levels of H_2S were observed at station 3 than at all other stations; station 5 also recorded significantly higher ($p<0.05$) values of H_2S concentration compared to stations 1 and 2, while only stations 3 and 5 recorded significantly higher ($p<0.05$) levels of H_2S than the control station. Monthly variations in the concentration of H_2S also showed significant difference, with January recording significantly higher ($p<0.05$) levels than all other months. The months of May-August also showed significantly lower ($p<0.05$) levels of H_2S than other months in the year.

The concentrations of H_2S in this study were more than ten times higher than the observed values in Mbaneme *et al*. (2014) which ranged from 0.001 – 0.004 ppm at the same study area; maximum levels of H_2S in this study were also higher than levels reported in Okrika commuities in Gobo *et al*., (2012). Studies by the Agency for Toxic Substances and Disease Registry as well as World Health Organisation have shown that exposure to high levels of H_2S can affect both the respiratory and nervous systems in humans, however no health effects have been found in humans exposed to typical environmental concentrations of hydrogen sulfide (0.00011-0.00033 ppm) (Chou *et al*., 2016; Selena & Chou, 2003). OSHA set an acceptable limit of 20 ppm for hydrogen sulfide in air (Chou *et al*., 2016). The observed concentrations of H_2S in this study were below the limit and therefore do not pose a threat to human health.

The concentrations of NH_3 ranged from 0.01ppm to 8.0ppm at station 3 with a mean of 0.3±0.1ppm in the wet season; <0.01ppm to 12.0ppm at station 3 with a mean of 1.0 ±0.2ppm in the dry season. The annual mean NH_3 concentration was 0.6 ±0.1ppm. NH_3 concentrations were much higher during the dry season than during the wet season. Analysis of variance for concentration of NH_3 in the study area revealed that both monthly and station variations in NH_3 levels show significant difference at $p<0.05$. Grouping information by months using Tukey method showed that significantly higher ($p<0.05$) levels of NH_3 were recorded at station 3 than at all other stations and control, while monthly variations showed significantly higher ($p<0.05$) concentrations of NH_3 for November and January compared to April - August.

The CO_2 concentrations ranged from 478 ppm at station 1 to 1011ppm at station 2 with a mean of 686±9ppm in the wet season; 446ppm at station 2 to 1064ppm at station 1 with a mean of 609 ±10ppm in the dry season. The annual mean CO_2 concentration was 654 ±7ppm. Analysis of variance for the concentration of CO_2 in the study area reveals that both monthly and station variations in CO_2 levels show significant difference at $p<0.05$. Grouping information by months using Tukey method revealed that the concentration of CO_2 is significantly higher for the month of September than for all other months. It also showed that CO_2 concentration recorded for the months of February, April and May were significantly higher than CO_2 concentration recorded for the months of June – August, October-January and March. Grouping information by station using Tukey method revealed that CO_2 concentrations were significantly higher at station 3 than at all other stations; levels of CO_2 at station 4 were also significantly higher than the levels at station 6. The levels at stations 3 and 4 were found to be significantly higher than the level at the control station (station 8).

The results from this study showed higher CO_2 concentrations when compared with Verla *et al*. (2018) which found that concentrations of CO_2 ranged from 500 to 579 ppm along River Nworie, Imo State, Nigeria. Mean levels of CO_2 were however similar to 653.00 – 745.53 ppm reported by Nwogbidi (2019) air quality

assessment in Obrikom /Omoku Industrial Area. Normal outdoor levels of 1000 ppm was recommended by ASHRAE and OSHA standards, however adverse health effects may be expected in concentrations ranging from 2500 – 5000 ppm (Engineering ToolBox, 2008). CO_2 is considered to be minimally toxic by inhalation, and the concentrations found in this study were below toxic threshold.

CO concentrations ranged from 0.01ppm to 12.30ppm at station 3 with a mean of 1.27±0.19ppm in the wet season and ranged from 0.01ppm to 14.00ppm at station 3 with a mean of 1.66 ±0.31ppm in the dry season. The annual mean CO concentration was 1.43 ±0.17ppm. CO concentration during the dry season (mean = 1.66ppm) were generally higher than during the wet season (mean = 1.27 ppm). Analysis of variance for concentration of CO in the study area reveals that both monthly and station variations in CO levels showed significant difference at $p<0.05$. August and September had significantly lower levels of CO compared with October- January while station level variations indicated significantly higher concentration of CO at station 3 compared to all other stations and significantly higher levels at station 4 and 5 compared to stations 1, 2, 6 and 7. The levels of CO at stations 3, 4 and 5 were found to be significantly higher than the levels at the control station (station 8).

The concentrations of Carbon monoxide recorded at the study area were below the recommended limits of 35 ppm by USEPA (2020) and 10 mg/m^3 (8.73 ppm) by WHO (2018) and NESREA (2014) except at station 3 (wet and dry season) and station 4 (dry season) which exceeded WHO and NESREA standards. The air quality index at station 3 ranged from moderate to unhealthy for sensitive groups. The most common sources of CO emission are motor vehicle exhaust which accounts for about 70% of air pollution (Topacoglu, *et al*., 2014). CO binds to hemoglobin over 200 times more easily than oxygen does thereby preventing oxygen from reaching tissues and organs (Tsubaki *et al*., 1982). At stations 3 and 4 of this study, anthropogenic sources of CO may be contributing to its high amounts in the atmosphere. O_3 concentrations was below the instrument detection limit of <0.02ppm in both wet and dry seasons.

$PM_{2.5}$ concentrations ranged from 1.4 µg/m^3 at station 1 to 96.8 µg/m^3 at station 3 with a mean of 8.3 ±0.9µg/m^3 in the wet season; 2.2µg/m^3 at station 1 to 97.8 µg/m^3 at station 2 with a mean of 25.2 ±1.8 µg/m^3 in the dry season. The annual mean $PM_{2.5}$ concentration was 15.3 ±1.0 µg/m^3. The dry season concentrations of $PM_{2.5}$ were generally higher than wet season levels with mean of 25.2µg/m^3 and 8.3µg/m^3 respectively. Analysis of variance for concentration of $PM_{2.5}$ in the study area reveals that both monthly and station variations in $PM_{2.5}$ levels show significant difference at $p<0.05$. Grouping information by months using Tukey method reveal that the concentration of $PM_{2.5}$ is significantly higher for the month of January than for all other months. It also showed that $PM_{2.5}$ concentration recorded for the months of December and February were significantly higher than $PM_{2.5}$ concentration recorded for the months of March – September. Grouping information by station using Tukey method revealed that $PM_{2.5}$ concentrations were significantly higher at station 3 than at all other stations; levels of $PM_{2.5}$ at the control station were also significantly lower than the levels at station 2 and 3.

The wet season concentrations of $PM_{2.5}$ in this study exceeded permissible limits of 25 µg/m^3, 35 µg/m^3 by WHO (2018) and USEPA (2020) at stations 1,2,3 and 7 but were below the 150 µg/m^3 set and FEPA (2003). In the dry season all stations exceeded the limits recommended by WHO and USEPA but were below FEPA limits. The air quality index for $PM_{2.5}$ was unhealthy in January for stations 1-7. Long-term exposure to $PM_{2.5}$ is associated with an increase in the long-term risk of cardiopulmonary mortality (WHO, 2013).

PM_{10} concentrations ranged from 4.1 µg/m^3 at station 8 to 72.5 µg/m^3 at station 3 with a mean of 14.4 ±0.8 µg/m^3 in the wet season; 3.8 µg/m^3 at station 1 to 264.4 µg/m^3 at station 3 with a mean of 55.9 ±5.3 µg/m^3 in the dry season. The annual mean PM_{10} concentration at the station was 31.8 ±2.6µg/m^3. The dry season concentrations of PM_{10} were generally higher than wet season levels. Analysis of variance for concentration of PM_{10} in the study area reveals that both monthly and station variations in PM_{10} levels show significant difference at $p<0.05$. Grouping information by months using Tukey method revealed that the concentrations of PM_{10} are significantly higher for the month of January than for all other months. It also showed that PM_{10} concentration recorded for the months of November, December and February were significantly higher than PM_{10} concentration recorded for the months of March – October. Grouping information by station using Tukey method revealed that PM_{10} concentrations were significantly higher at station 3 than at all other stations; levels of PM_{10} at the control station were also significantly lower than the levels at station 1, 2 and 3.

The wet season concentrations of PM_{10} in this study were below permissible limits of 50 µg/m^3 and 150 µg/m^3 by WHO (2018) and USEPA (2020) respectively except station 3 which exceeded WHO limits. In the dry season all stations exceeded the limits recommended by WHO. The air quality index for PM_{10} was unhealthy in January for stations 1-7. Long-term exposure to PM_{10} is associated with an increase in the long-term risk of cardiopulmonary mortality (WHO, 2013). Air pollution due to PM_{10} poses a considerable risk to the environment and to human health. The air quality index of the study area showed that the air was unhealthy in the months of January – March for stations 1-3, and November - December for station 3 alone.

Air quality parameters measured at the study area showed some correlations. VOC showed highly positive significant correlation with PM_{10} ($r = 0.734$), positive but moderate significant correlation with CH_4, CO, H_2S and NH_3 with correlation coefficients $r = 0.542$, 0.556, 0.639 and 0.518 respectively. This shows that

the concentrations of VOC in air at the study areas are highly related to the concentrations of PM_{10}. The US EPA report on the environment states that VOC play a role in the formation of secondary organic aerosols, which are found in airborne particulate matter (USEPA, 2018). This may have resulted in the high correlation values between VOC and PM_{10}. PM_{10} also showed positively significant but moderate correlation with H_2S, NH_3 and Cu, with r = 0.564, 0.542 and 0.503 respectively. Other significant correlations were between H_2S and NH_3 with moderate significance (r = 0.641), between temperature and relative humidity with high significance (r = -0.786) and between relative humidity and heat radiation (r = -0.545).

Table 3: Wet and Dry Seasons Levels of Air Pollutants Measured at the Study Area

Parameter	WET SEASON				DRY SEASON			
	Min	Max	Mean	SEM	Min	Max	Mean	SEM
NO_2 (ppm)	0.002	0.077	0.020	0.001	0.003	0.086	0.029	0.002
VOC (ppm)	1.00	6.90	2.05	0.09	0.01	12.80	3.23	0.26
SO_2 (ppm)	0.01	1.42	0.05	0.01	0.01	1.15	0.07	0.01
CH_4 (ppm)	0.1	5.0	0.4	0.1	0.1	8.0	0.9	0.1
H_2S (ppm)	0.01	0.50	0.03	0.01	0.00	0.55	0.07	0.01
NH_3 (ppm)	0.1	8.0	0.3	0.1	0.0	12.0	1.0	0.2
CO_2 (ppm)	478	1011	686	9	446	1064	609	10
CO (ppm)	0.01	12.30	1.27	0.19	0.01	14.00	1.66	0.31
O_3 (ppm)	0.02	0.02	0.02	0.00	0.02	0.02	0.02	0.00
$PM_{2.5}$ ($\mu g/m^3$)	1.4	96.8	8.3	0.9	2.2	97.8	25.2	1.8
PM_{10} ($\mu g/m^3$)	4.1	72.5	14.4	0.8	3.8	264.4	55.9	5.3

Table 4: Annual Levels of Air Pollutants Measured at the Study Area

	ANNUAL VALUES			
Parameter	**Min**	**Max**	**Mean**	**SEM**
NO_2 (ppm)	0.002	0.086	0.024	0.001
VOC (ppm)	0.01	12.80	2.54	0.13
SO_2 (ppm)	0.01	1.42	0.06	0.01
CH_4 (ppm)	0.1	8.0	0.6	0.1
H_2S (ppm)	0.01	0.55	0.05	0.01
NH_3 (ppm)	0.0	12.0	0.6	0.1
CO_2 (ppm)	446	1064	654	7
CO (ppm)	0.01	14.00	1.43	0.17
O_3 (ppm)	0.02	0.02	0.02	0.00
$PM_{2.5}$ ($\mu g/m^3$)	1.4	97.8	15.3	1.0
PM_{10} ($\mu g/m^3$)	3.8	264.4	31.8	2.6

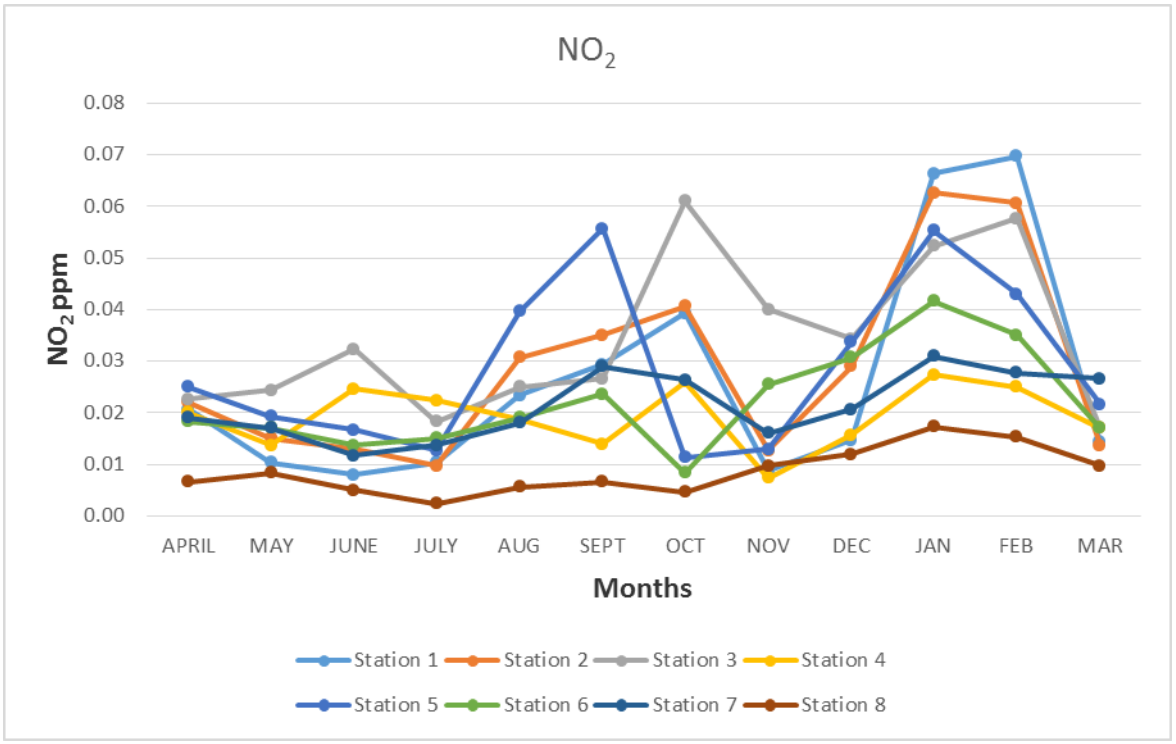

Fig 11 Monthly Variations in NO_2 Concentrations at the Study Area

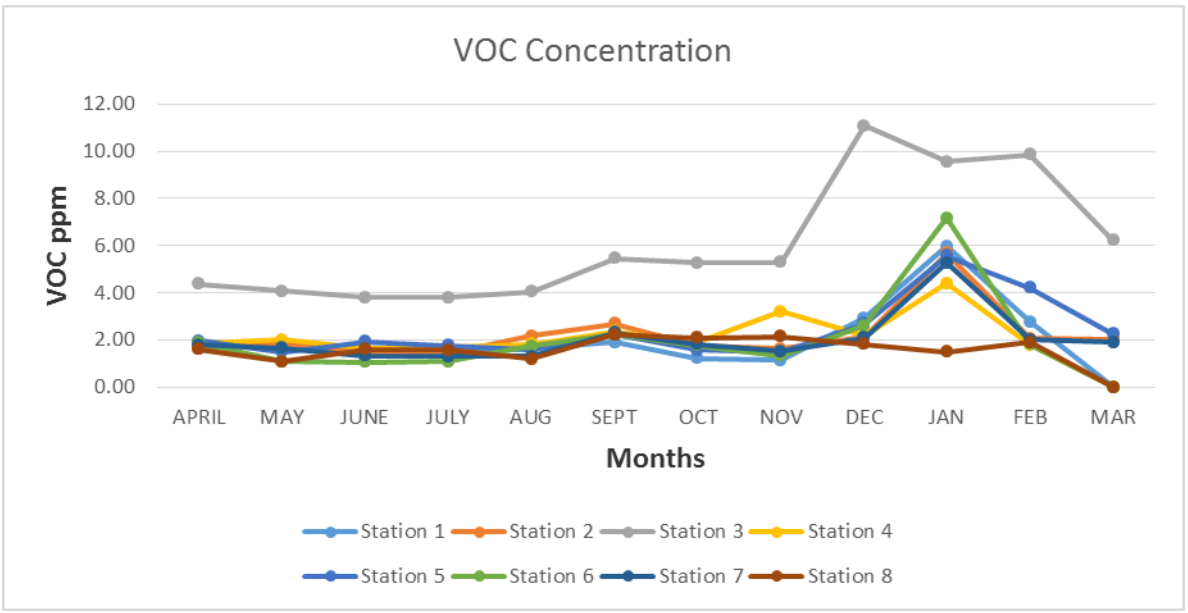

Fig. 12 Monthly VOC Concentration in the Study Area

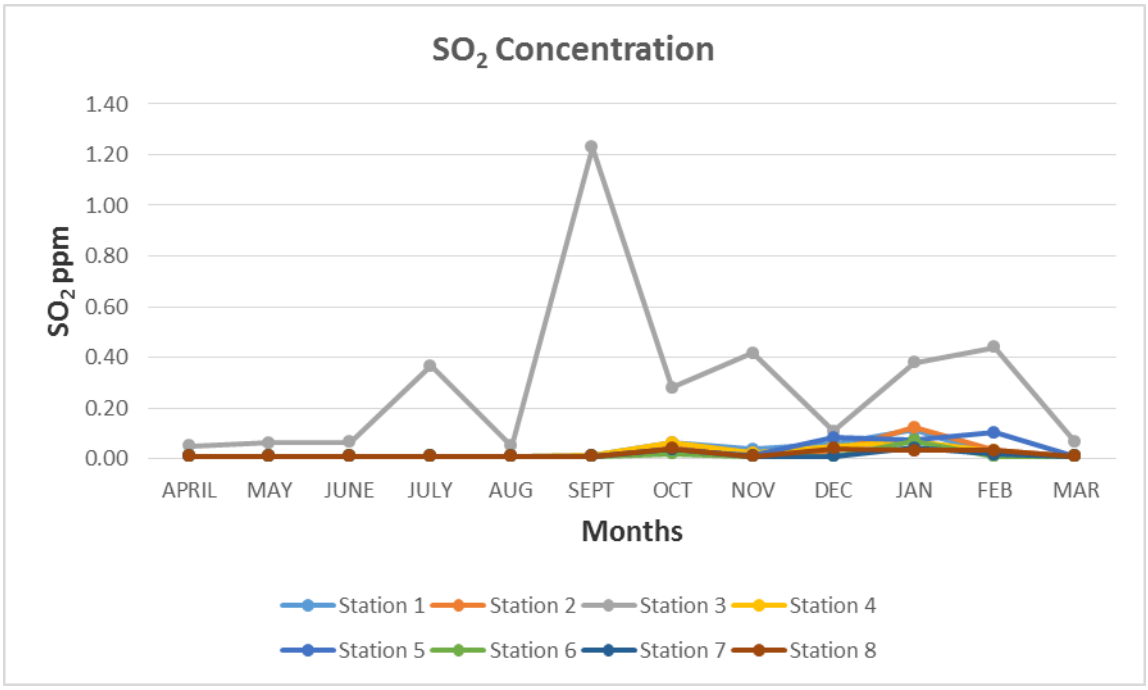

Fig 13 Monthly SO_2 Concentration in the Study Area

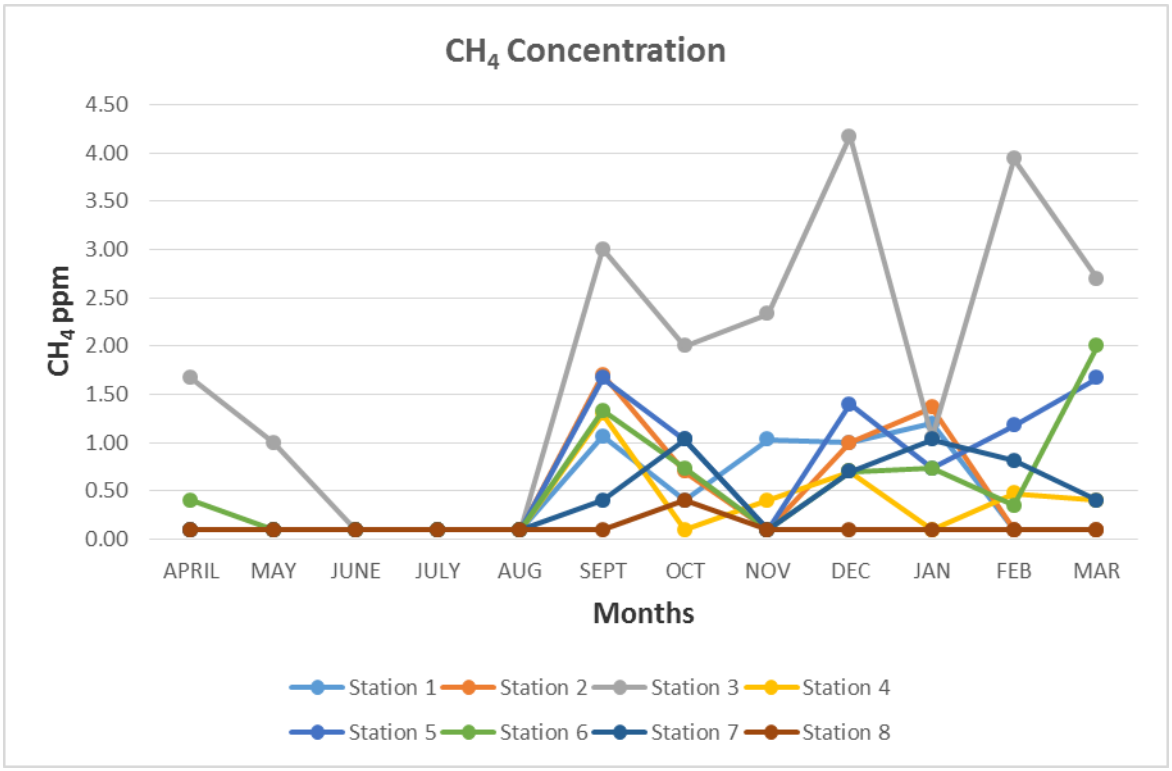

Fig 14 Monthly CH_4 Concentration in the Study Area

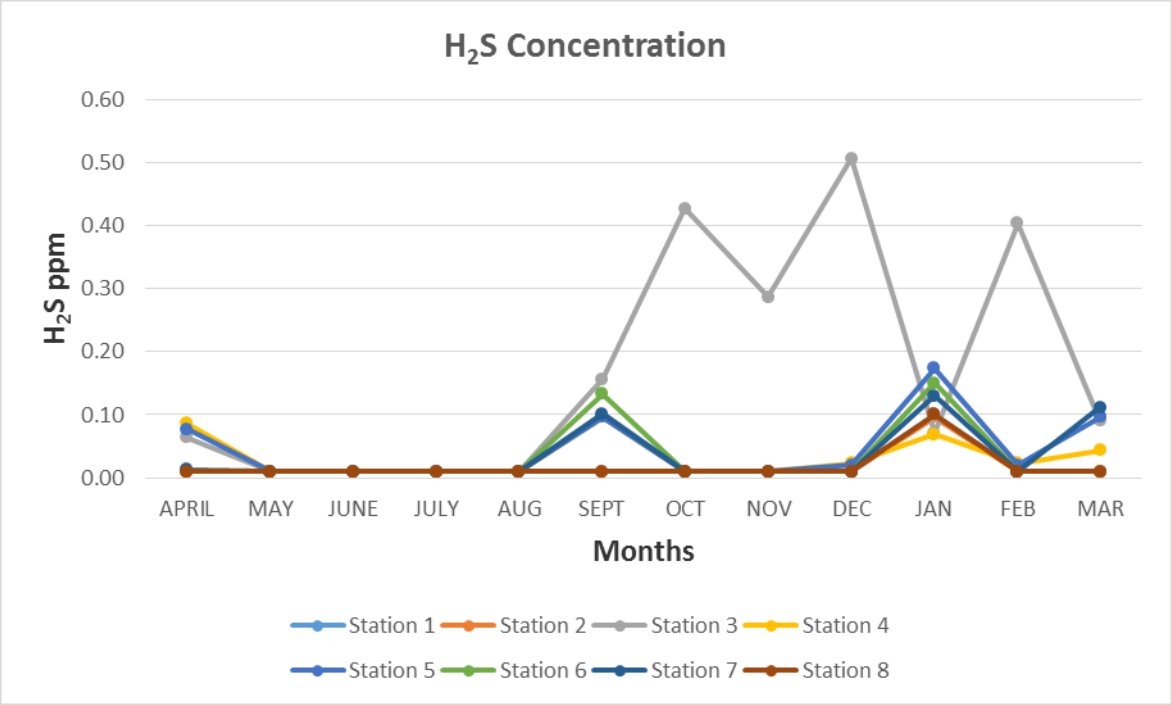

Fig 15 Monthly H_2S Concentration in the Study Area

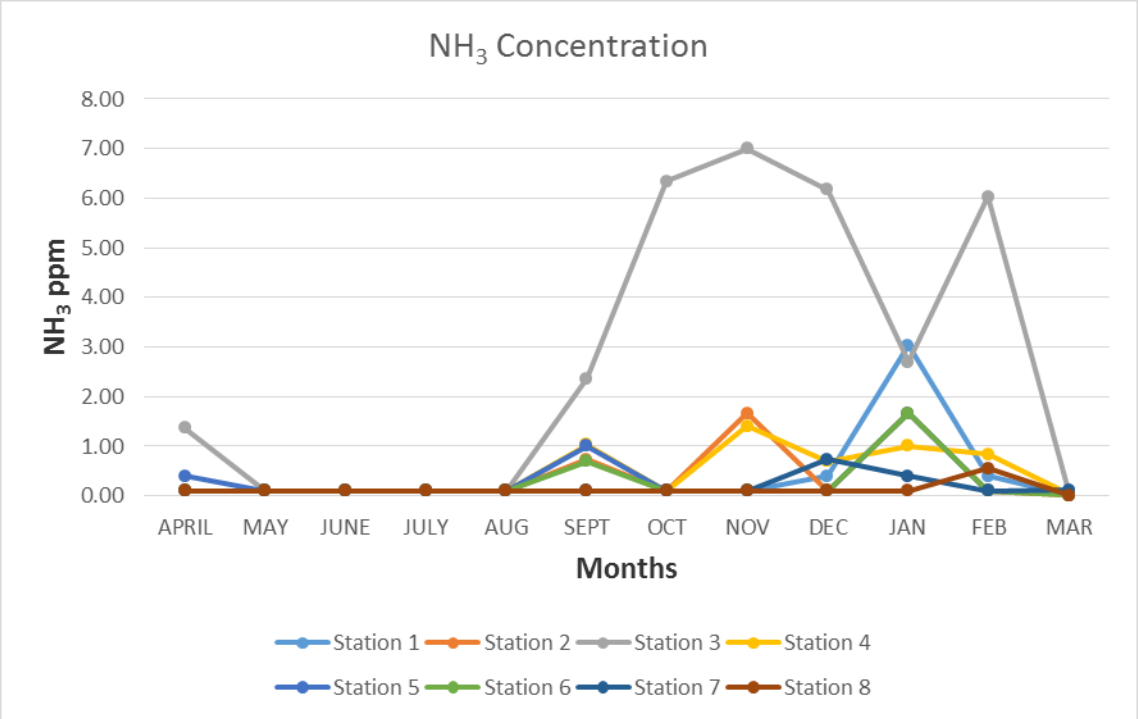

Fig 16 Monthly NH_3 Concentration in the Study Area

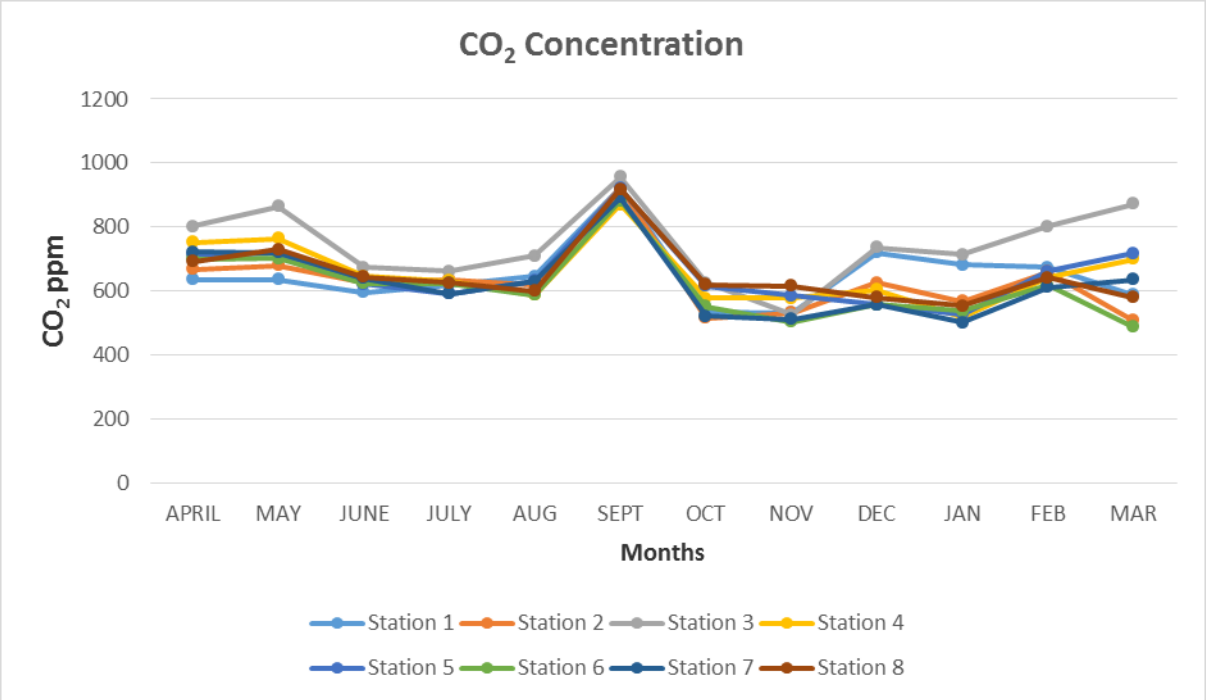

Fig 17 Monthly CO_2 Concentration in the Study Area

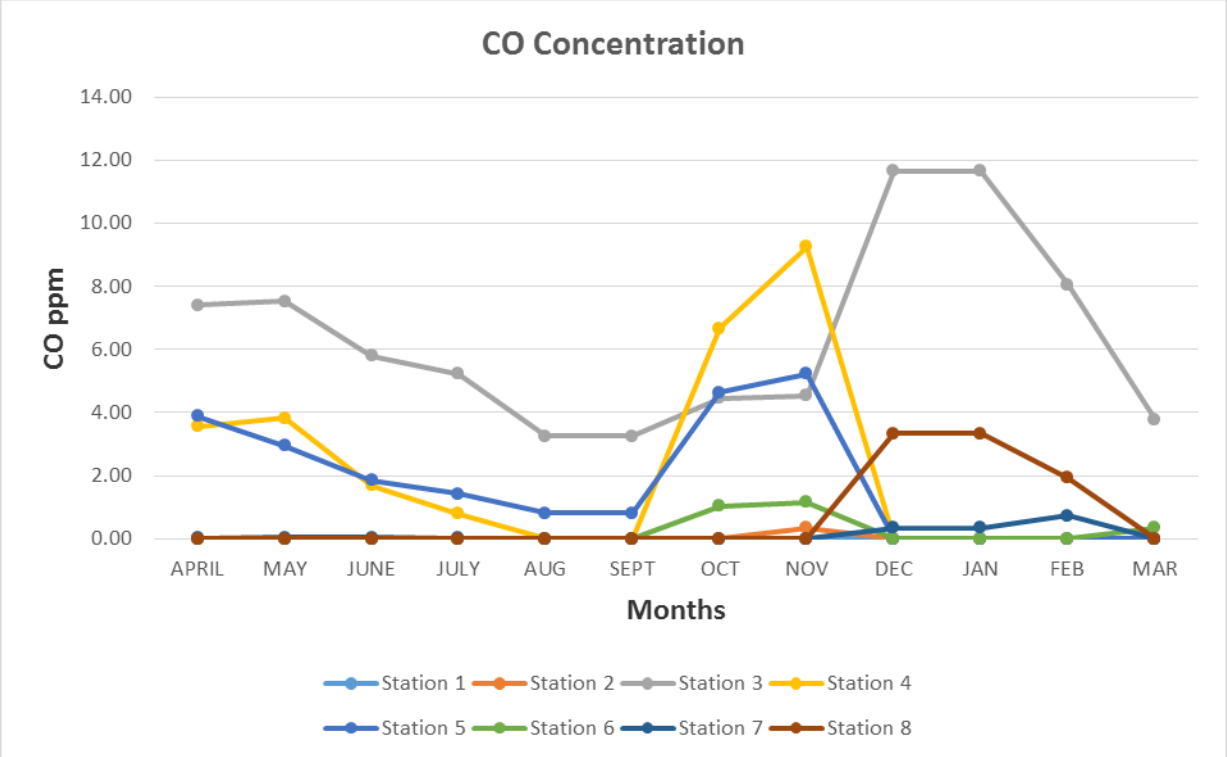

Fig 18 Monthly CO Concentration in the Study Area

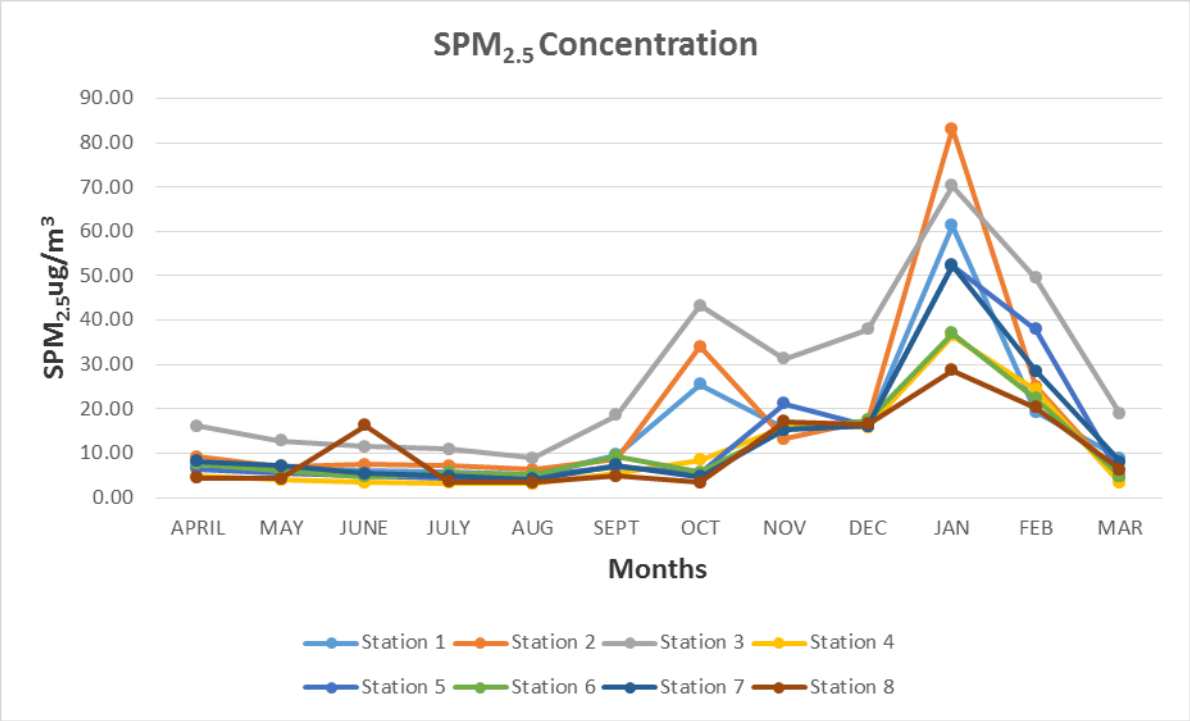

Fig 19 Monthly $SPM_{2.5}$ Concentration in the Study Area

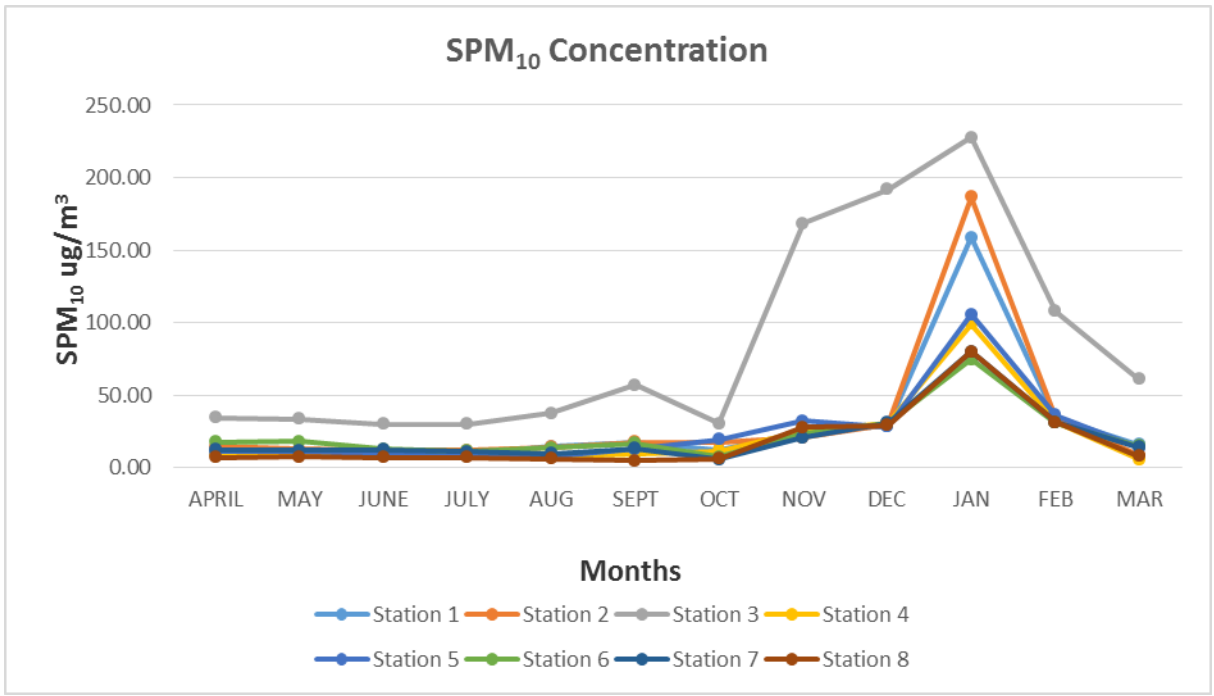

Fig 20 Monthly SPM_{10} Concentration in the Study Area

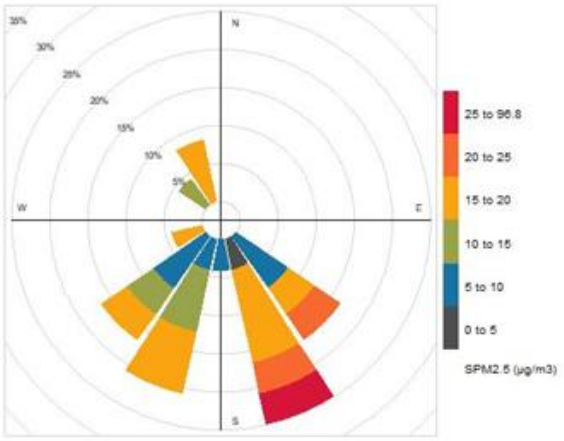

Fig 21: Wet Season PM_{10} for Station 3

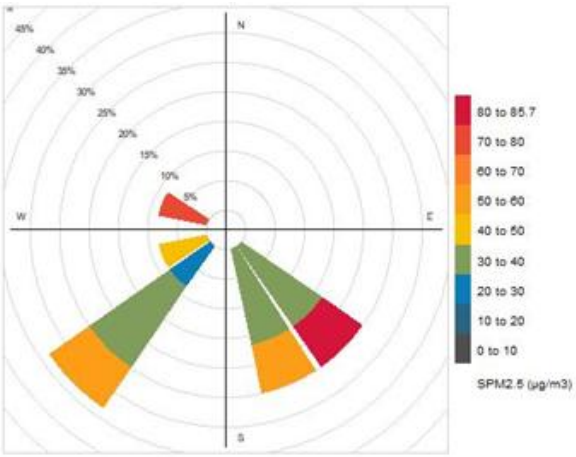

Fig 22: Dry Season PM_{10} for Station 3

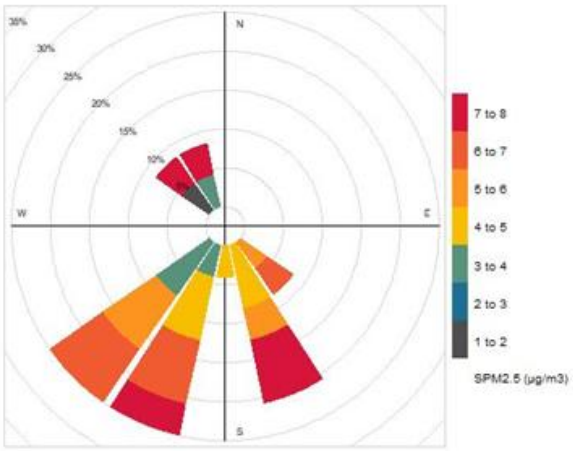

Fig: 23 Wet Season $PM_{2.5}$ for Station 5

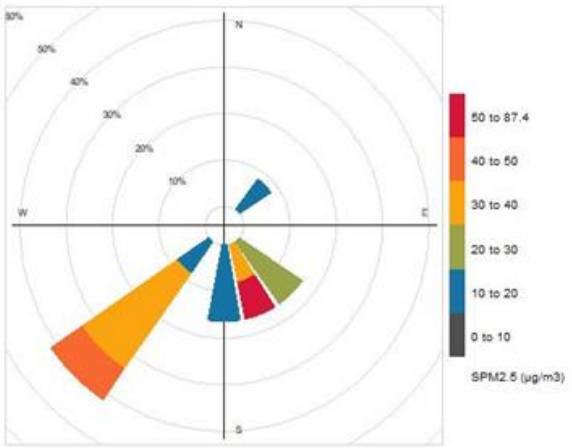

Fig 24: Dry Season $PM_{2.5}$ for Station 5

Particulate Matter

The results of Air Quality Index (AQI) for $PM_{2.5}$, PM_{10}, NO_2, SO_2, CO and O_3 in air at the study area are presented in Tables 5 to 11.

Table 5: Air Quality Index Scale as defined by the USEPA NAAQS/DPR/FMEnv Standard

Air Quality Index Values (AQI)	Air Pollution Level	Health Implications	Colors
0 to 50	Good	Air quality is considered satisfactory, and air pollution poses little or no risk	Green
51 to 100	Moderate	Air quality is acceptable; however for some pollutants, there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution	Yellow
101 to 150	Unhealthy for sensitive group	Members of sensitive groups may experience health effects. The general public is not likely to be affected	Orange
151 to 200	Unhealthy	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects	Red

201 to 300	Very Unhealthy	Health warnings of emergency conditions. The entire population is more likely to be affected	Purple
301 to 500	Harzardous	Health alert: everyone may experience more serious health effects	Maroon

Table 6: Air Quality Index for $PM_{2.5}$ from April 2019 to March 2020 at the Study Area

AQI ($PM_{2.5}$) _USEPA NAAQS / DPR / FMEnv.

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	154	65.9	37.1	30.8	28.3	25.0	24.2	21.7	40.0	79.2	58.4	59.4
2	165	78.3	17.5	38.3	29.2	31.3	29.6	26.3	36.3	97.1	53.5	62.1
3	159	135	65.3	59.6	52.5	48.3	45.4	37.5	64.5	120	91.4	107
4	103	76.7	13.8	20.0	16.7	14.2	13.8	12.9	22.9	35.4	59.0	58.8
5	142	107	20.0	26.7	22.9	20.4	18.3	20.0	29.2	22.9	70.1	59.4
6	105	72.7	20.0	31.7	25.0	19.6	23.3	21.3	38.8	23.8	57.7	62.1
7	143	85.7	33.3	34.2	29.6	22.9	20.0	17.1	30.4	19.6	57.7	59.4
8	85.7	68.2	26.3	18.3	17.9	59.6	15.0	14.2	20.0	14.6	61.7	60.5

Table 7: Air Quality Index for PM_{10} from April 2019 to March 2020 at the Study Area

AQI (PM_{10}) _USEPA NAAQS / DPR / FMEnv.

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	103	31.3	14.9	10.2	10.1	9.44	9.17	13.4	15.8	10.9	23.1	26.4
2	116	31.7	7.96	13.6	11.9	11.1	11.1	13.1	16.4	16.5	19.3	28.1
3	137	77.2	54.1	32.1	31.1	27.8	28.1	34.9	53.0	28.4	107	119
4	72.8	29.1	5.19	8.80	8.89	7.78	7.50	7.13	8.61	10.7	23.2	28.3
5	76.2	33.7	12.8	10.5	10.6	8.89	8.33	7.22	11.8	18.1	30.0	26.3
6	60.8	28.5	14.0	16.2	16.8	11.8	10.6	12.8	15.5	7.04	21.6	28.1
7	63.4	29.3	13.2	11.4	11.0	11.4	10.2	8.89	12.4	5.28	19.2	28.7
8	63.4	28.9	7.50	6.57	6.85	6.48	6.48	5.65	4.54	5.93	25.6	27.0

Table 8: Air Quality Index for NO_2 from April 2019 to March 2020 at the Study Area

AQI (NO_2) _USEPA NAAQS / DPR / FMEnv.

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	63.8	68.0	13.2	19.8	9.43	7.55	9.43	21.7	27.4	36.8	8.49	14.2
2	60.6	58.5	13.2	20.8	14.2	12.3	9.4	29.2	33.0	38.7	12.3	27.4
3	49.1	55.3	16.0	21.7	22.6	30.2	17.0	23.6	25.5	58.5	37.7	32.1
4	25.5	23.6	16.0	18.9	13.2	23.6	20.8	17.9	13.2	24.5	6.60	15.1

5	52.1	40.6	20.8	23.6	17.9	16.0	12.3	37.7	53.1	10.4	12.3	32.1
6	39.6	33.0	16.0	17.0	16.0	13.2	14.2	17.9	22.6	7.55	24.5	29.2
7	29.2	26.4	25.5	17.9	16.0	11.3	13.2	16.98	27.4	24.5	15.1	19.8
8	16.0	14.2	9.43	6.60	7.55	4.72	1.89	5.66	6.60	4.72	9.43	11.3

Table 9: Air Quality Index for SO_2 from April 2019 to March 2020 at the Study Area

AQI (SO_2) _USEPA NAAQS / DPR / FMEnv.

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	116	14.3	14.3	14.3	14.3	14.3	14.3	14.3	14.3	81.2	56.0	81.2
2	121	42.9	14.3	14.3	14.3	14.3	14.3	14.3	14.3	81.2	28.6	42.9
3	226	246	81.2	68.6	81.2	93.7	223	68.6	612	190	239.1	116
4	93.7	42.9	14.3	14.3	14.3	14.3	14.3	14.3	14.3	81.2	28.6	69
5	93.7	112	14.3	14.3	14.3	14.3	14.3	14.3	14.3	42.9	14.3	103
6	93.7	14.3	14.3	14.3	14.3	14.3	14.3	14.3	14.3	28.6	14.3	14.3
7	56.0	28.6	14.3	14.3	14.3	14.3	14.3	14.29	14.3	56.0	14.3	14.3
8	42.9	42.9	14.3	14.3	14.3	14.3	14.3	14.29	14.3	56.0	14.3	56.0

Table 10: Air Quality Index for CO from April 2019 to March 2020 at the Study Area

AQI (CO) _USEPA NAAQS / DPR / FMEnv.

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114
2	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	3.86	0.114
3	138	86.6	43.1	80.0	81.3	64.0	58.3	37.2	37.2	50.6	51.5	138
4	0.114	0.114	0.114	40.5	43.4	19.2	8.98	0.114	0.114	72.8	98.7	0.114
5	0.114	0.114	0.114	44.2	33.6	21.1	16.1	9.20	9.20	52.3	58.3	0.114
6	0.114	0.114	3.98	0.114	0.114	0.114	0.114	0.114	0.114	11.70	13.30	0.114
7	3.86	8.41	0.114	0.227	0.455	0.455	0.341	0.114	0.114	0.114	0.114	3.86
8	37.8	22.0	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	0.114	37.8

Table 11: Air Quality Index for O_3 from April 2019 to March 2020 at the Study Area

AQI (O_3) _USEPA NAAQS / DPR / FMEnv.

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5
2	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5
3	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5
4	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5
5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5

6	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5
7	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5
8	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5

IV. CONCLUSION

The results indicated that the communities were exposed to moderate to high concentrations of CO, SO_2, $PM_{2.5}$ and PM_{10} which may adversely affect their health conditions under prolonged exposure. Air quality index at station 3 was particularly hazardous for SO_2 and therefore requires urgent attention to mitigate the risk of exposure for residents within this location. The control station generally showed significantly lower levels of gaseous pollutants and particulates than the study stations. With the assessment of air quality at the study area it is recommended that industrial activities and other practices by the residents in the study area should be curtailed by Government. Also due to high levels of SO_2 in air, the impact of acid rain on plants, surface water and buildings should be assessed.

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