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Assessment of Particulate Matter Concentrations in Ambient Air in Khana and Gokana Local Government Area Rivers State Nigeria

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Abstract:- The impacts of high concentrations of particulate matter in ambient air due to incessant anthropogenic activities have become a tremendous concern as regards to public health issues associated with it. This study aimed at assessing some meteorological parameters and particulate matter concentrations in ambient air around Bodo and Bori the largest communities in Ogoni in Rivers State. Okwale and Bera-Mogho communities, distant from the study areas, served as control 1 and control 2 respectively. Meteorological parameters and particulate matter were determined in-situ using digital portable hand held monitors. The results showed that wind direction alternated between South West (SW), North West (NW) and North East (NE). Relative humidity (%) ranged from 55.35 to 69.45 with a mean of 64.06±4.96. Ambient Temperature (^oC) ranged from 30.55 to 33.05 with a mean of 31.74±0.87. Wind speed (m/s) ranged from 3.1 to 4.25 with a mean value of 3.69±0.49. $PM_{2.5}$, PM_{10} and SPM recorded concentrations were below WHO and NAAQS recommended limits. The results showed that most control stations showed higher levels of meteorological parameters and particulate matter than some of the study locations. This was attributed to diverse anthropogenic activities such as automobile activities, illegal artisanal refinery of crude oil and some domestic activities. The study concluded that the exposures to particulate matter in the stations are considered satisfactory and air pollutants pose little or no risk. The study therefore recommended that further Studies on other Pollutants including gases should be monitored in more rural areas around Ogoni Communities.

Keywords:- *Particulate Matter, Air Pollutants, Ambient Air, Ogoni, Nigeria.*

I. INTRODUCTION

Air is known to be a basic necessity required for any human existence (Akinfolarin *et al*., 2017). However, due to natural and anthropogenic activities this environmental compartment has been severely deteriorated with inimical substances such as particulate matter (PM), Sulphur oxides, Nitrogen oxides, Carbon (II) oxide. This interruption with the cleanliness of air in its natural state has become a major environmental issue both in developed and developing countries of the world (Munir *et al*., 2017). This is caused by industrialization and urbanization which has resulted to higher concentration of human populace in cities with feasible economic opportunities such as commercial communities and cities (Koop and Van-Leewen, 2017).

Any substance in the air which could affect human health and have a great impact on the environmental compartment is defined as air pollutants. According to the World Health Organization (WHO, 2014), particle pollution, CO, ground-level O_3, nitrogen oxides (NO_X), sulfur oxides (SO_X), and lead (Pb) are the six major air pollutants which causes great harm to human health and the ecosystem at large. There are also pollutants of suspended materials such as fumes, dust, gaseous pollutants, polycyclic aromatic hydrocarbons (PAHs), smokes, mists, hydrocarbons, halogen derivatives, volatile organic compounds (VOCs), and ammonia (NH_3) in ambient air (clean air) which at higher concentrations cause vulnerability to many diseases including cancers and eventual death (Rodopoulou *et al*., 2014).

Urban cities are known with different activities ranging from small scale industries which include glass, ceramics and textile industries, to sales and distribution of electronics and household items, abattoir services, auto-repairs, shopping malls, markets, hotel and restaurants, from freelance street side trading and small units of cigarettes (Ezejiofor *et al*., 2013). This activity over a long period of time have led to rapid increase in motor vehicles, illegal artisanal refineries, roasting of animals with tyres, burning of bushes, welding activities and burning of large amount of municipal waste generated in these cities and communities which generates particulate matter in air (Njoku *et al*., 2016).

According to Sadeghi *et al.* (2015) particle pollutants are one of the major components of ambient air pollutants. Particulate matter is a mixture of particles found in ambient air. Particle matter which is termed as PM is connected with most of the pulmonary and cardiac-associated morbidity and mortality. They vary in size ranging mostly from 2.5 μm to 10 μm ($PM_{2.5}$ to PM_{10}).

The size of the particle matter is directly connected with the initial phase and progression of the lungs and heart diseases. Particles with small size can reach the lower respiratory tract and have higher potential for causing the lungs and heart diseases. In addition, numerous scientific reports have shown that fine particle matter cause premature death in people with heart or lung disease. It could also result to nonfatal heart attacks, cardiac dysrhythmias, aggravated asthma and decreased lung functions. Depending on the level and degree of exposure, particulate matter may result in mild to severe illnesses. Cough, wheezing, dry mouth and limitation in some activities due to breathing problems are the some of the prevalent clinical symptoms of respiratory disease resulted from ambient air pollution (Guillam *et al.,* 2013).

Nkin (2023) reported that long-term exposure to ambient particulate matter concentrations can lead to a marked reduction in life expectancy. The main reasons for the reduction in life expectancy is the increase of cardiopulmonary and lung cancer mortality. Reduced lung functions in children and adults leading to asthmatic bronchitis and chronic obstructive pulmonary disease (COPD) are also serious diseases which induce lower quality of life and reduced life expectancy. There is strong evidence on the effect of long-term exposure to particulate matter on cardiovascular and cardiopulmonary mortality come from cohort studies (Zhou *et al.*, 2014).

Adoki (2012) in an air quality survey in four different locations in Rivers State at varying distances (60, 100, and 500 m) from emission source found that, virtually all the samples were within the Department of Petroleum Resources (DPR) guidelines for annual average. Akinfolarin *et al.* (2018) in a review on the air quality characteristics of emerging industrial areas in Port Harcourt reported that elevated levels of inhalable particulate matter at the stations during the study period suggest the possibility of associated human health effects. Other studies have shown that the levels of particulate matter concentrations ranged from unsafe, unhealthy and very unhealthy for human health (Oweisana *et al.*, 2021; Ideriah *et al.*, 2020; Okey-Wokeh *et al.*, 2020; Angaye *et al.*, 2019).

Khana and Gokana LGAs in Rivers State are examples of places that are seriously affected because of major oil spills, illegal artisanal refinery operations in addition to other anthropogenic sources such as open burning of refuge and vehicular activities which introduce particulates, gases, sooth and dust constantly into ambient air. Residents living nearby areas where these activities take place are vulnerable populace due to greater concentrations of potential toxic elements and persistent pollutants; and the population experience more frequent exposure. Frequent exposure to potential toxic elements and persistent pollutants can lead to asthma attacks, irritation of nose, eyes, mouth and throat, reduce lung functioning, headache and dizziness, wheezing and coughing, neuro behavioral disorders especially in children, cardiovascular problems, cancer, and premature death (Ideriah et al., 2023; Sadeghi *et al.*, 2015).

Therefore, it is important to investigate the levels of particulate matter and meteorological parameters at the study area. An analysis of the health risks from particulate matter exposure will create awareness to the population on the quality of air they are exposed to and provide an overview of the adverse impacts that a population may experience. This will also ameliorate the general knowledge of the link between air pollutants and its health impacts thereby enhancing improvements of the air quality in the communities.

II. MATERIALS AND METHODS

➢ *Description of the Study Area*

Bori is the largest city in Khana Local Government Area, Rivers State, Southern Nigeria. Bori city is situated approximately on Latitude 4.67482° or 4° 40' 29" N Longitude 7° 21' 56" E with a population of about 117,797 people. Bori has an elevation of 18 metres (59 feet) (NPC, 2006). Bori is also known as the traditional headquarters of the Ogoni people. It serves as a business and commercial centre for the Ogoni, Opobo-Nkoro, Andoni, Annang and other ethnic groups of the Niger Delta region. Bori is also the second largest city in Rivers state and the commercial center of the Rivers State southeast senatorial district.

Bodo is a community in Gokana Local Government Area of Rivers State. Bodo city is situated within Latitude 4° 37′ N and longitude 7° 16′ E with a population of about 49,000 people. Bodo city is the largest indigenous community in Rivers State (NPC, 2006).

The meteorological conditions of Gokana and Khana display climatic characteristics which can be termed as semi-hot equatorial zone. The climate is characterized with high humidity with annual mean ranging between 72 % - 81 % and heavy rainfalls with annual mean ranging between 3,000 mm- 4,000 mm). The wet season is long, which runs between seven and eight months of the year, usually from the months of March to October (called rainy season). There is normally a short break around August, which is referred as "August break". The dry season begins in the month of November and runs till February or March; a period of approximately three months however; the atmosphere sustains enough moisture throughout the year (Gobo and Abam, 1991). The climate characteristics are usually governed by the general circulatory style of two air masses: the dry dusty North-East Trade wind (Tropical continental air masses) from the Sahara Desert which always come in the dry season, ushering in the harmattan from December to January and the moisture southwest wind (tropical maritime air masses) which bring rain during the rainy season. The meteorological characteristic of the prevailing wind patterns in the study location shows that the wind direction perseveres from the southwest for most of the year (Ojo, 1977). Generally the temperatures are high in the region and favourably constant throughout the year. The mean monthly maximum temperature varies between 28 ºC to 33 ºC and minimum temperature varies between 21 ºC to 23 ºC respectively, an increase northward and westward and the warmest months being February, March and early April. The coolest months are June through to September during the peak of the rainy season. The map of Khana and Gokana LGAs showing the study location is shown in Figure 1.

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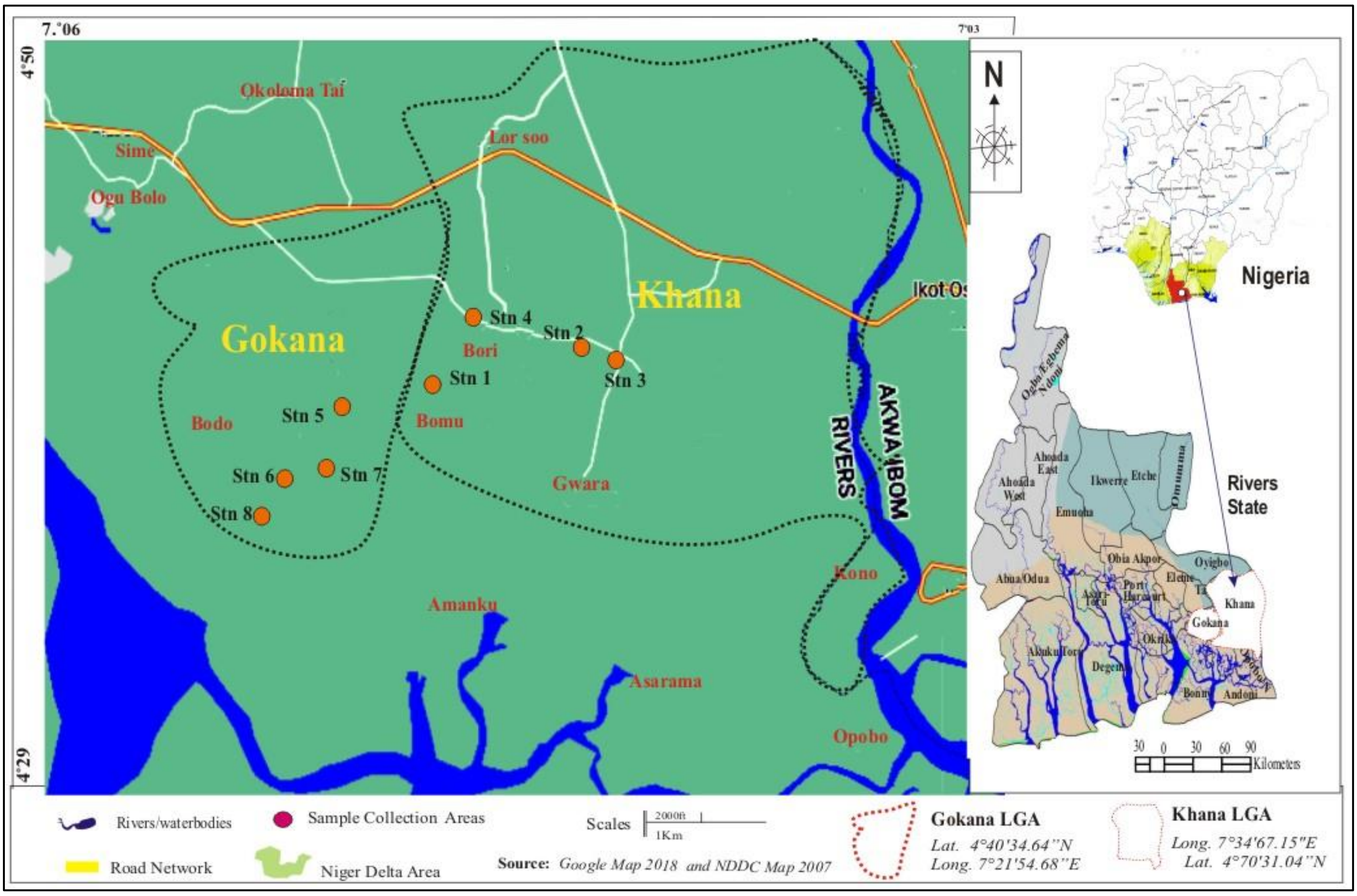

Fig 1 Map of Khana and Gokana Showing Sampling Stations

➢ *Sampling Frequency*

Particulate matter and meteorological parameters were monitored for two (2) months (August and September, 2023) across eight stations; namely (1) Okwale road, (2) General hospital gate Bori, (3) Ken Saro Wiwa polytechnic campus main gate Bori, (4) Bori Main Market, (5) Bera road, (6) Station junction Bodo, (7) Bodo- Bonny road and (8) Bodo city market. The samplings were carried out for two (2) hours in each station across the eight (8) stations that were chosen for the study.

➢ *Determination of Meteorological Conditions*

- *Wind Speed and Direction*

Wind direction and speed were determined with a hand-held digital Kestrel weather tracker anemometer. At each station, an anemometer was switched on and allowed to stabilize for 5 minutes. The anemometer was held up in an open space with respect to the average height of the human. This was to avoid unnecessary interferences from shades after which readings were read off and recorded.

- *Relative Humidity*

Humidity was measured using a hand-held digital Kestrel weather tracker hydrometer with a range of 0-100%. At each station the equipment was switched on and allowed to stabilize for 5 minutes after which readings were read off and recorded.

- *Ambient Temperature*

Ambient temperature was measured using a hand-held 4250 Kestrel weather tracker thermometer. At each station the thermometer was switched on and allowed to stabilize for 5 minutes. The thermometer was held up in an open space with respect to the average height of the human, to avoid unnecessary interferences from shades after which readings were read off and recorded.

➢ *Determination of Particulates (SPM, $PM_{2.5}$, and PM_{10})*

A hand-held digital aeroquol 500 series monitor was implored to measure SPM, $PM_{2.5}$, and PM_{10} at the study area. The aeroquol 500 series monitor was pre-calibrated before using for better quality assurance purposes. At each station the monitor was switched on and allowed to stabilize for 5 minutes. The monitor was held up in an open space with respect to the average height of a human. Each reading was read off and recorded when the equipment stabilizes and switched off thereafter.

➢ *Air Quality Index (AQI)*

The Sim-air quality software was used to calculate the AQI of the air pollutants using equation below (Swemgba *et al*., 2019).

$$I_P = \frac{I_{HI} - I_{LO}}{BP_{HI} - BP_{LO}} (C_P - BP_{LO}) + I_{LO} \qquad 1$$

I_P = Index for pollutant P
C_P = Actual ambient concentration of pollutant P
BP_{HI} = Breakpoint that is greater than or equal to C_p
BP_{LO} = Breakpoint that is less than or equal to C_p
I_{HI} = AQI value corresponding to BP_{HI}
I_{LO} = AQI value corresponding to BP_{LO}

The AQI is divided into six groups with a specific colour assigned to each to comprehend if air contaminants are approaching unhealthy levels in the area as shown in Table 1 (USEPA, 2011).

Table 1 Air Quality Index Scale as Defined by 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 the sensitive groups may experience health effect. The general public is not likely to be affected.	Orange
151 to 200	Unhealthy	Everyone may begin to experience health effects. Members of the 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	Hazardous	Health alert: everyone may experience more serious health effects	Maroon

III. RESULTS

➢ *Meteorological Parameters*

The results of meteorological parameters are presented in Table 2 and Figs. 2- 4. The ambient temperature values at the study area ranged from 30.55°C to 33.05°C with a mean value of 31.74±0.87°C. The relative humidity values ranged between 55.35 % to 69.45 % with a mean value of 64.06±4.96 %. Wind direction alternated between North West (NW) and South West (SW) in August and between North East (NE) and South West (SW) in September. The wind speed ranged from 3.1m/s to 4.25m/s with a mean value of 3.69±0.49m/s.

Table 2 Variations in the Levels of Meteorological Parameters at the Study Area

Stations	Tempt (°C)			Rel Hum (%)			WS (m/s)			WD (m/s)	
	Aug	Sept	Mean	Aug	Sept	Mean	Aug	Sept	Mean	Aug	Sept
1	32.9	31	31.95±1.34	60.9	60.7	60.8±0.14	3.6	2.9	3.25±0.49	NW	NE
2	30.1	31.9	31±1.27	67.6	66.8	67.2±0.56	3.6	2.6	3.1±0.70	NW	NE
3	30.2	32.3	31.25±1.48	68.7	69.4	69.05±0.49	3.9	2.8	3.35±0.77	NW	NE
4	31.3	31.5	31.4±0.14	64	64.5	64.25±0.35	3.9	2.8	3.35±0.77	NW	SW
5	30.5	30.6	30.55±0.07	69.4	69.5	69.45±0.07	4.4	3.1	3.75±0.91	SW	NE
6	33.4	32.2	32.8±0.84	54.8	55.9	55.35±0.77	5	3.4	4.2±1.13	SW	NE
7	33.3	32.8	33.05±0.35	60.2	59.8	60±0.28	5	3.5	4.25±1.06	SW	SW
8	31.5	32.4	31.95±0.63	66.1	66.7	66.4±0.63	5	3.5	4.25±1.06	SW	SW

SW- South West NW- North West NE- North East

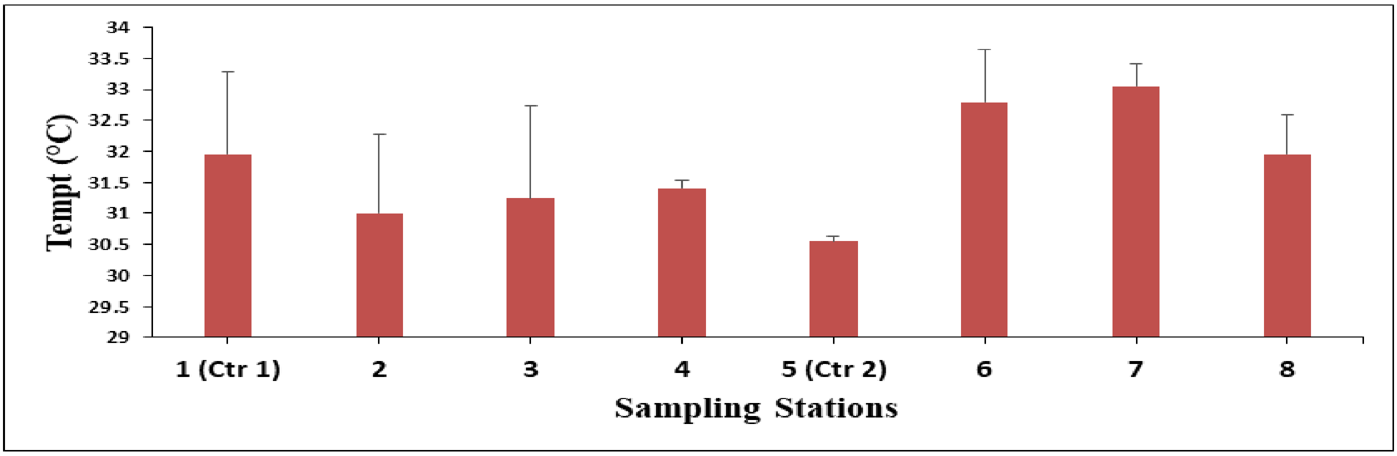

Fig 2 Mean Ambient Temperature at the Study Area

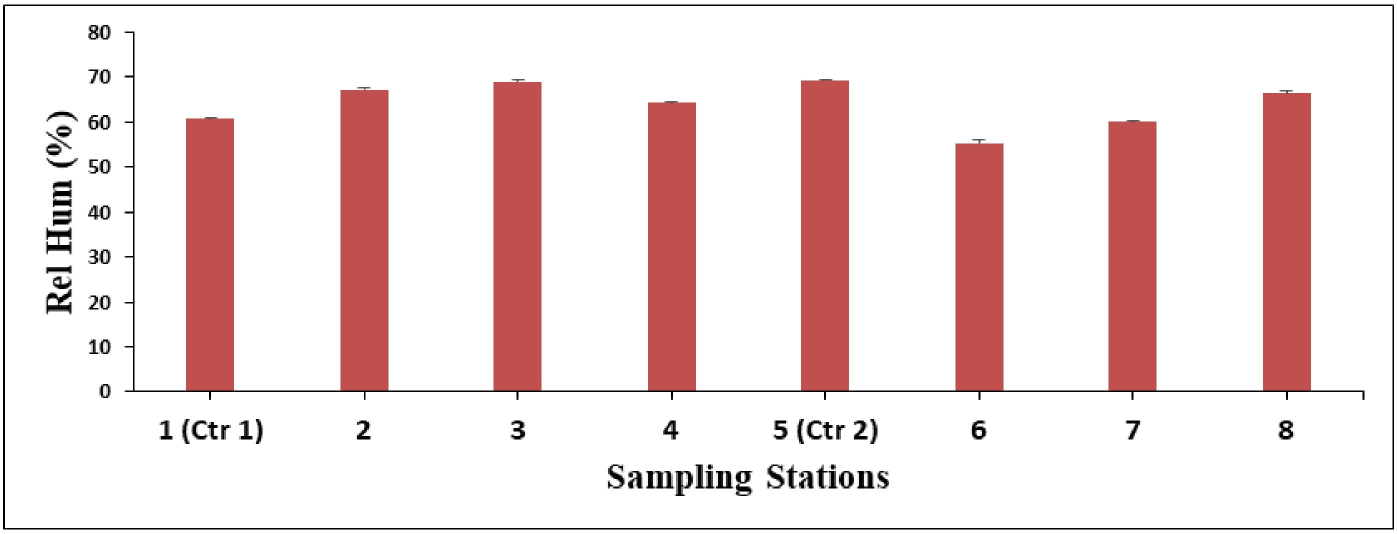

Fig 3 Mean Relative Humidity at the Study Area

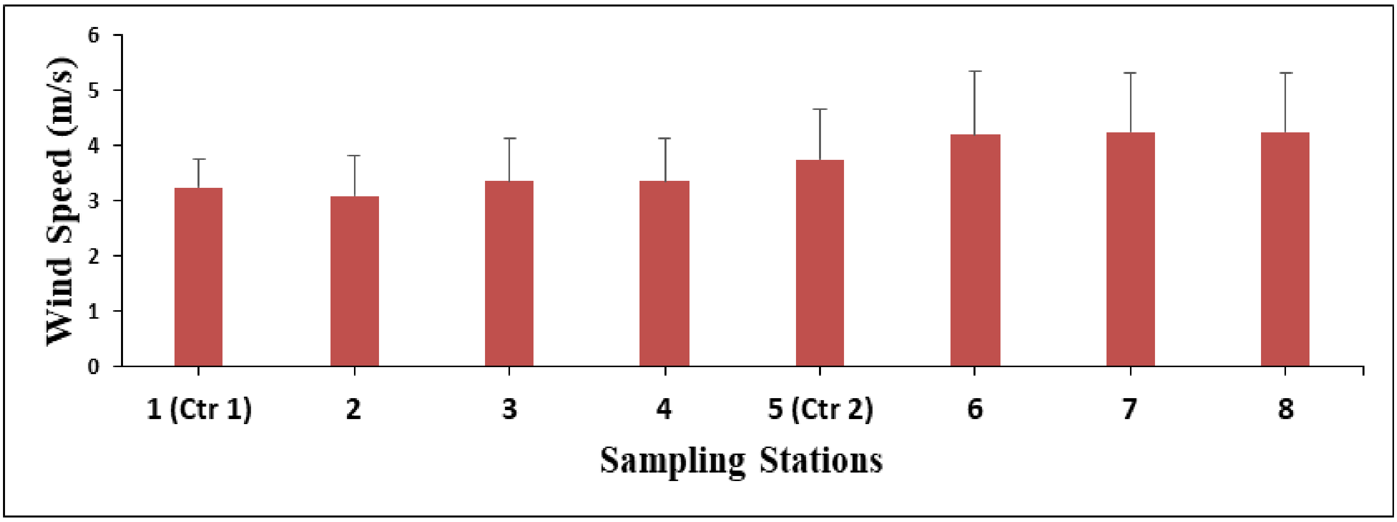

Fig 4 Mean Wind Speed at the Study Area

➢ *Particulate Matter*

The results of particulate matter are presented in Figs. 5 - 6 $PM_{2.5}$ concentrations ranged from 5.5µg/m^3 to 7.5µg/m^3 with a mean value of 6.19±0.84µg/m^3. PM_{10} concentrations ranges from 6.5µg/m^3 to 9.5µg/m^3 with mean value of 8.03±0.89µg/m^3. SPM concentrations ranged from 12.5µg/m^3 to 16µg/m^3 with mean value of 14.13±1.09µg/m^3.

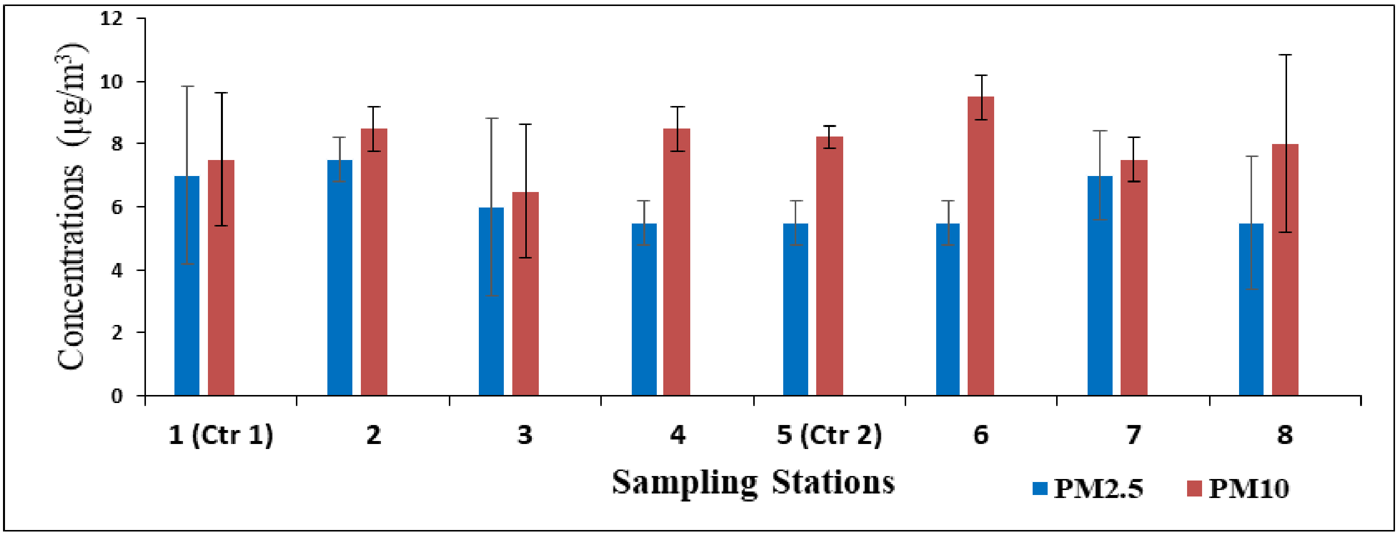

Fig 5 Mean Concentrations of $PM_{2.5}$ and PM_{10} at the Study Area

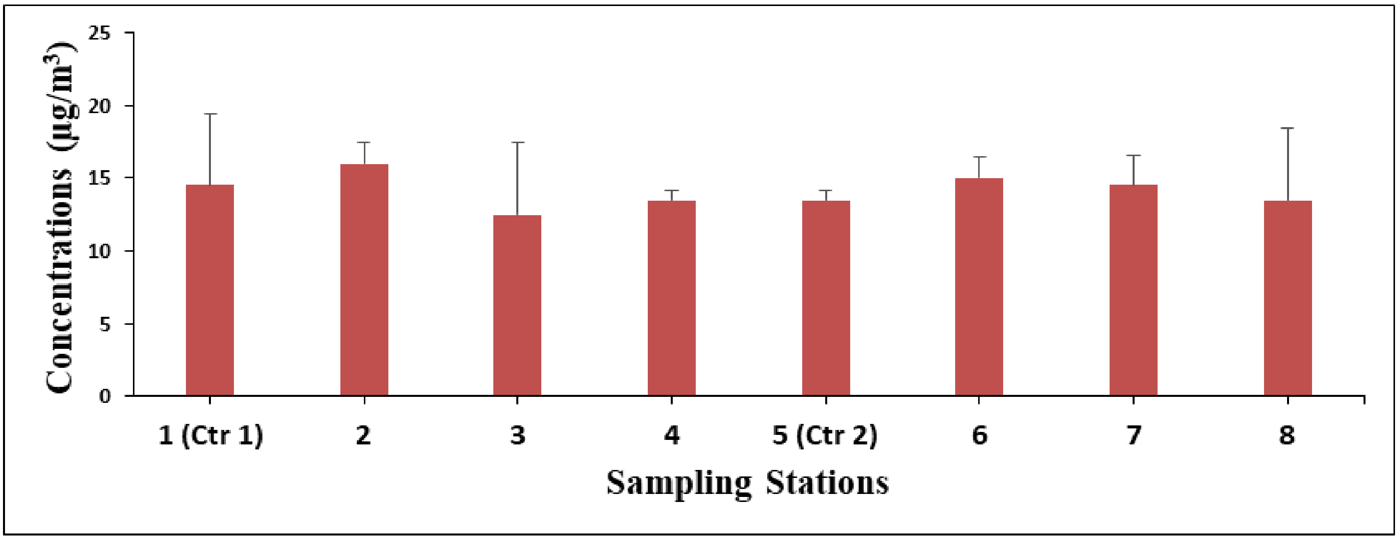

Fig 6 Mean Concentrations of SPM at the Study Area

➢ *Air Quality Index (AQI)*

The results of the AQI data from the study area are presented in Table 3. The AQI for the $PM_{2.5}$ ranged from 17 to 38. The AQI for the PM_{10} ranged from 6 to 9.

Table 3 Air Quality Index for PM2.5 and PM10 at the study Area

		$PM_{2.5}$		PM_{10}
Stations	**Aug**	**Sept**	**Aug**	**Sept**
1	38	21	8	6
2	29	33	7	8
3	17	33	5	7
4	21	25	7	8
5	25	21	7	7
6	25	21	9	8
7	25	33	6	7
8	17	29	6	9

IV. DISCUSSION

➢ *Meteorological Parameters*

The results in Table 2 shows that the ambient temperature values at the study area ranged from 30.55°C at station 5 to 33.05°C at station 7 with a mean of 31.74±0.87°C. Atmospheric temperature is higher in September than August although both months are rainy season. It revealed that September is characterized by moderate amount of precipitation and more of sunshine. Typically September ushers in the dry season (November to February). During this period, evaporation exceeds precipitation, leading to increased aridity and high temperature (Uko and Tamunobereton-Ari, 2013). The observed difference in ambient temperature at the study stations was as a result of different time of the day that the measurement was carried out. The high temperature could also be attributed to decrease in the water (moisture) content of ambient air around the study area due to prevalence of the harmattan winds; which were dry, cold and dust laden. Other factors which contributed to the higher values were increased use of biomass fuel for cooking and drying around the study locations, illegal artisanal refinery of crude and other domestic activities at the study locations (Salau, 2016). The ambient temperature values obtained were in consonance with the findings of Omoku *et al.* (2021) which recorded a mean temperature of 31.52°C in parts of Onne and Akinfolarin *et al.* (2018) which recorded 31.47±0.49°C, 30.52±0.60°C and 30.03±0.70°C for Eleme, Oginigba and Rumuolumeni respectively. The results of ambient temperature values from this study are opposed to Alagoa and Derefaka (2012) who stated that temperature is significantly constant throughout the state with a maximum of 30°C.

Wind speed ranged from 3.1m/s at station 2 to 4.25m/s in both station 7 and 8 with a mean value of 3.69±0.49m/s. the highest wind speed was recorded in August. Wind speed which is a measure of air ventilation has a direct impact on indoor and outdoor thermal comfort. The study of Oweisana *et al.* (2021) has shown that the morphology of urban areas as well as coverage of building significantly decreases air ventilation. Other beneficial aspects 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 (Oweisana *et al.*, 2021). The results from the study shows that wind direction alternated between North West (NW) and South West (SW) in August and between North East (NE) and South West (SW) in September.

The result from this study showed higher wind speed values when compared with Oweisana *et al.,* (2021), in their measurement of wind speed in Obrikom and Omoku communities in Rivers State. They found an aggregate mean wind speed of 0.9m/s. However, the results of this study showed lower wind speed values when compared to Oyewole and Aro (2008) in their measurement of wind speed pattern in Nigeria. They found an aggregate mean speed in Port Harcourt to be 5.51m/s which is higher than the 3.69m/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 55.35% at station 6 to 69.45% at station 5 with a mean of 64.06±4.96% during the study. The values obtained from relative humidity from the study area are consonant with the results by Oweisana *et al.* (2021) which stated that September recorded a monthly mean of over 60%.

Relative humidity is a representation of the percentage of water vapour in ambient air that transforms with the air temperature. The observed variation in the levels of relative humidity in the stations during the study period may be attributed to the different in the amount of moisture in the air as well as air temperature. Generally, when it rains, it can have a considerable impact on the humidity in the air (Mawonike and Mandonga, 2017).

Temperature and humidity directly impacts people's comfort level and their health (Dotson, 2018). Generall, relative humidity below 25% makes people feel uncomfortably dry, while relative humidity above 60% makes people feel uncomfortably humid (Dotson, 2018). Flu and influenza viruses tend to thrive when outdoor temperatures grow colder. Research shows that aerosolized influenza viruses are more suitable for low relative humidity (Lowen and Steel, 2014). At the study area, the risk of infection of flu will be low due to high relative humidity during this period.

- *Particulate Matter*

$PM_{2.5}$ concentrations ranged from 5.5µg/m^3 at stations 4, 5, 6 and 8 to 7.5µg/m^3 at station 2 with a mean value of 6.19±0.84µg/m^3. Levels of $PM_{2.5}$ concentrations at station 1 (Control 1) was significantly higher than the levels at station 3, 4, 6 and 8. Station 5 (control 2) has same $PM_{2.5}$ concentrations with 4, 6 and 8.

The concentrations of $PM_{2.5}$ in this study in all stations were below the permissible limits of 35µg/m^3 and 15µg/m^3 recommended by NAAQS (2017) and WHO (2021) respectively. These results were in line with the report of Gobo *et al.* (2012) in Okrika communities who recorded values below permissible limits. The observed $PM_{2.5}$ values are opposed to Oweisana *et al.* (2021) who had values higher than the permissible limits in Obrikom and Omoku communities.

PM_{10} concentrations ranged from 6.5µg/m^3 at station 3 to 9.5µg/m^3 at station 6 with a mean value of 8.03±0.89µg/m^3. Station 6 had the highest level of PM_{10} concentrations when compared to other stations. Levels of PM_{10} at station 5 (control 2) were significantly higher than the levels at station 3, 7 and 8 while station 1 (control 1) was significantly higher than station 3 and had the same concentrations with station 7. The concentrations of PM_{10} in this study in all stations were below the permissible limits of 150µg/m^3 and 45µg/m^3 recommended by NAAQS and WHO.

SPM concentrations ranged from 12.5µg/m^3 at station 3 to 16µg/m^3 at station 2 with a mean value of 14.13±1.09µg/m^3. The SPM concentration of station 1 (control 1) was higher than station 3, 4, 5 and 8 and has the same SPM concentration with station 7. Station 5 (control 2) has a higher SPM concentration to station 3 but had same concentration with station 4 and 8. The SPM concentrations in this study in all stations were below the permissible limits of 250µg/m^3 and 150µg/m^3 recommended by NAAQS AND WHO.

- *Air Quality Index (AQI)*

Air Quality Index (AQI) is an overall estimate of the status of a place under review. The AQI values were ascertained in order to evaluate the human health risk which the populace are exposed to due to ambient air pollution. The maximum AQI for $PM_{2.5}$ was 38 while the maximum AQI for PM_{10} was 9 as shown in Table 3. These AQI values were good for all stations. According to Table 3.3; Exposure to particulate matter in the stations is considered satisfactorily and air pollutants poses little or no risk. These observed AQI values obtained were in consonance with the results of Gobo *et al.* (2012) who reported that air quality was satisfactorily and air pollutants poses little or no risk in Okrika communities, Rivers State.

However, these results were contrary to the findings of Okey-Wokeh *et al.* (2020) who reported AQI was unhealthy and according to the Table 1; the populace which are exposed to this pollutants may start to experience health effects. Populations which are known as the sensitive groups may experience more severe health effect in Aba, Port Harcourt and Elele-Alimini communities.

V. CONCLUSION

Assessment of particulate matter concentrations in ambient air around some ogoni communities found that $PM_{2.5}$, PM_{10} and SPM recorded concentrations where below WHO and NAAQS recommended limits. The results showed that most control stations showed higher levels of meteorological parameters and particulate matter than some of the study locations. This was attributed to diverse anthropogenic activities such as automobile activities, illegal artisanal refinery of crude oil and some domestic activities. The study concluded that the exposures to particulate matter in the stations are considered satisfactory and air pollutants pose little or no risk. The study therefore recommended that further Studies on other Pollutants including gases should be monitored in more rural areas around Ogoni Communities.

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