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Full Length Research

An Assessment of Particulate Matter Pollution in Calabar, Nigeria

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The present investigation was carried out for assessment on the level of particulate matter ($PM_{2.5}$, PM_{10}, Total Suspended Particulate (TSP)) pollution in Calabar during (2015-2016). The result of the research showed that for $PM_{2.5}$, Atamunu by Mount Zion station in Calabar is the most polluted in terms of $PM_{2.5}$ concentration. While export processing zone (EPZ) tank farm was found to be the cleanest place in terms of $PM_{2.5}$ concentration in ambient air. For PM_{10}, NNPC tank farm station was found to have the highest concentration of PM_{10} in ambient air, hence the most polluted in terms of PM_{10}. Cross River State University of Technology (Crutech) gate station had the least concentration of PM_{10}. It is considered as the safest place to be in terms of PM_{10} pollution. For TSP, Crutech gate station has the highest concentration of TSP in ambient air. It is considered to be the most polluted in Calabar. The mean concentration of $PM_{2.5}$ for all the stations under study fell below the Nigerian Nation air quality standard for $PM_{2.5}$ which is 300μg/m^3 for annual mean and 500 μg/m^3 for 24hr mean. The mean concentration of PM_{10} for Ambo Market station which was 160.5μg/m^3 was above the National standard of 120μg/m^3 annual average and 150μg/m^3 24hr average. At NNPC tank farm station, the mean concentration of 134.39μg/m^3 was above the National standard of 120μg/m^3 annual average. The concentration measured in the other stations were below the national standards. For TSP, the measured concentrations were below the National standard for all the stations.

Key Words: Pollution; concentration; quality; standard; stations.

INTRODUCTION

Environmental problems caused by particulate matter (PM) pollution has undoubtedly been enormous, with its greatest impact being on human health Wang et al., (2008). Hence, the poor air quality

in the developing countries is responsible for the high health risk posed by pollution Orogade et al., (2016). Undoubtedly, the different states of the federation are affected by this particulate matter pollution, especially the most populated and most industrialized. In her report for CNN cable network, Park, (2016), wrote "Dirtied by success? Nigeria is city with worst PM_{10} levels". She mentioned that Onitsha is the worst polluted city for air quality when measuring PM_{10} concentration. However, Nigeria did not feature in the top 10 for $PM_{2.5}$ levels.

Different sources produce PM in Nigeria. The different states of the country may face different challenges in PM pollution. The Sources of particulate matter ($PM_{2.5}$) pollution in Kaduna state include, residual oil (49%), Soil (29%), continental dust (18%) and motor vehicle emissions (4%) while PM_{10} sources include Soil (50%), Continental dust (21%), Vehicular emissions (18%) and petrochemical (11%) Orogade et al., (2016). Other sources of PM pollution in Nigeria include; firewood and stove combustion (Onabowale and Owoade, 2015), petrochemical (Otu and Oloidi, 2018), burning of sawdust Okadere et al. (2017), traffic, Industry, sea spray and biomass burning, wind-blown dust, marine and crustal matter (Taiwo et al., 2015), crustal dust and fuel-oil (Anake et al., 2016), dusty football fields (Seiyaboh et al., 2019), Power generating set and regional black carbon (soot) (Osimobi and Nwankwo, 2018). Research has shown that PM pollution is more severe during the dry season compared to the wet season (Ubong et al., 2011); Ngele and Onwu, 2015; Akinfolarin et. al., 2017; Abali et al., 2018). Also, established is the fact that PM pollution is higher in Nigeria during weekdays compared to weekends (Owoade et al., 2013). Wind also plays a very important role in the dispersion of pollutants. Hence, PM concentration is high upwind and low downwind (Ubong et al., 2015). High levels of PM pose high adverse environmental and health implication such as climate change, acid rain, agricultural loss, psychological effects. Petrochemical pollution causes destruction of Zinc roof, depletion of ozone layer, decay of concrete walls and contributes a lot to economic loss (Otu and Oloidi, 2018).

Health implications of PM pollution include; pertussis, pulmonary tuberculosis, cerebrospinal meningitis (CSM), pneumonia, measles, chronic bronchitis and upper respiratory tract infection (URT) (Nwachukwu et al., 2012). The main aim of this research is to monitor and analyze particulate matter (PM) concentration in Calabar city.

MATERIALS AND METHODS

The present research was conducted at Calabar, South Nigeria during (2015-2016). The city is watered by the Calabar River and Great Qua Rivers Creeks of the Cross River. Its Coordinates are Latitude: 5^{o} 16'07.6"N; Longitude: 8^{o} 23' 34. 56E. Calabar covers an area of 604km^{2}. Aerocet 5315 particle mass/ particle count was used for measuring particulate matter ($PM_{2.5}$, P.M. $_{10}$). The different particulate matter sizes which include, $PM_{2.5}$, PM_{10} and TSP. The particle sampler does not have any warm up time. When it is put on at the location of interest, it takes samples of the air, processes it and the displays the values of all the different particulates present at the location. Another set of data for this research was obtained by an AQM65 equipment. The data for this research were obtained in two parts. The first was obtained from the mobile Aeroqual hand held devices while the second part was obtained from the stationary AQM65 device stationed at the University of Calabar main station. The data from the mobile devices were obtained at specific time intervals and at specific days. The days data were taken are; 23/05/2015, 06/06/2016, 20/06/2016, 04/07/2016, 18/07/2016, 1/08/2016, 15/08/2016 and 29/08/2016. On the other hand, the AQM65 stationary device was programmed by the company to record data at a minute by minute interval. The machine could also be re-programmed to record data at an hourly interval. For the purpose of this research, the data was obtained in a minute by minute interval. The data from both devices were presented as monthly means. For the purpose of these research, six locations within Calabar metropolis were selected for the mobile data taking. These stations include; Cross River University of Technology (CRUTECH) gate, Ambo market, Atamunu by mount zion, NNPC tank farm, University of Calabar main station, Export processing zone (EPZ) tank farm. This is shown in Table 1 The stationary equipment is stationed at the University of Calabar main station.

RESULTS AND DISCUSSION

Particulate matter ($PM_{2.5}$, PM_{10} and TSP) data was obtained for the six stations considered for this research. The data assess the extent of PM pollution in Calabar metropolis. The average concentration of the data is presented in Figures 1 to 3. Figure 1 is a pie chart showing the average concentration of $PM_{2.5}$

Table 1. Stations considered for the research.

S/N	STATION	LATITUDE	LONGITUDE	ELEVATION(m)
1	Crutech Gate	4°55'53.1''	8°19'42.0''	26
2	Ambo Market	4°56'15.2''	8°19'0.2''	43
3	Atamunu by Mount Zion	4°56'23.5''	8°19'44.5''	22
4	Unical Main Station	4°57'07.78''	8° 20' 51''	62
5	NNPC Tank Farm	5°01'01.12'	8°19'29.3''	61
6	EPZ Tank Farm	5°01'08.1''	8°19'20''	53

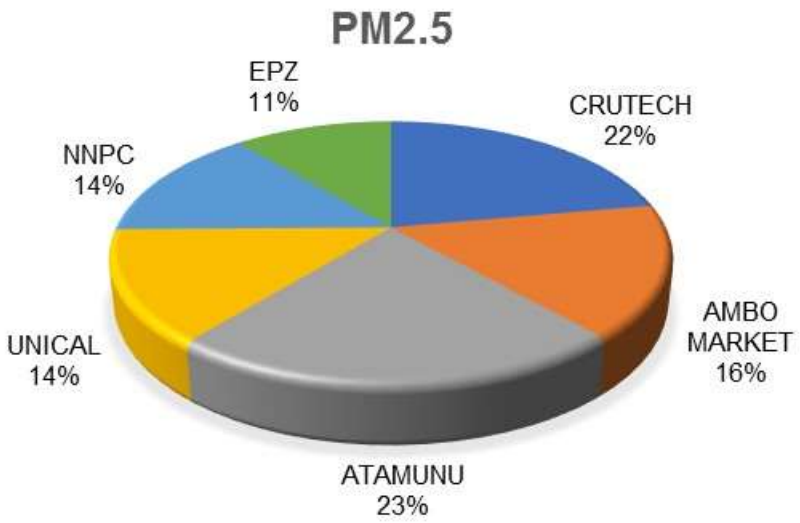

Figure 1. Pie chart showing $PM_{2.5}$ concentration in percentage.

measured at selected dates. The diagram shows that Atamunu station had the highest concentration of $PM_{2.5}$ (23%) while EPZ had the least concentration of $PM_{2.5}$ (11%). Figure 2 shows concentration of PM_{10} for the selected locations. It can be seen that NNPC tank farm station had the highest concentration of PM_{10} (24%) while Crutech gate station had the least concentration of PM_{10} (7%). Figure 3 shows the concentration of TSP. It can be seen that Crutech gate station had the highest concentration of TSP (29%) while EPZ and Unical stations had the least concentration of TSP (9%) and (10%) respectively. When compared to the research carried out in Ploiesti city, Romania in 2017 which had $PM_{2.5}$ concentration to be (20 - 354) $\mu g/m^3$. That of PM_{10} was (22 – 190.5) $\mu g/m^3$ (Iordache et al., 2017). It can be seen that it is comparable. In Dahaka, Bangladesh, in 2006, $PM_{2.5}$ was 66.2 $\mu g/m^3$, PM_{10} was 75.5 $\mu g/m^3$ while TSP concentration was 263 $\mu g/m^3$ (Salam et al., 2008).

Figures 4 to 6 shows concentration plots of PM for the different locations. Figure 4 shows concentration plots for $PM_{2.5}$. The diagram shows that Atamunu station had the highest concentration of $PM_{2.5}$(~70$\mu g/m^3$) on the 23rd of May 2016. While EPZ Tank Farm station had the least concentration of $PM_{2.5}$ (~10$\mu g/m^3$) as measured on the 6th June 2016. EPZ recorded the lowest concentration of $PM_{2.5}$ throughout the study duration. However, the concentration recorded was below the Nigerian National ambient air quality standard of 300$\mu g/m^3$ (Annual) and 500$\mu g/m^3$ (24Hrs) for $PM_{2.5}$. Figure 5 shows the concentration plots for PM_{10}. The plot shows that NNPC station recorded high concentration in multiple dates. It also shows that PM_{10} concentration exceeded the Nigerian national

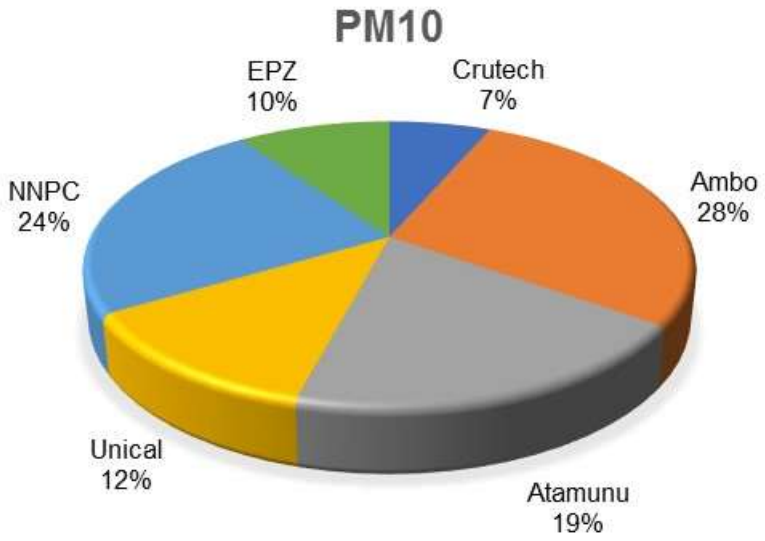

Figure 2. Pie chart showing PM_{10} concentration in percentage.

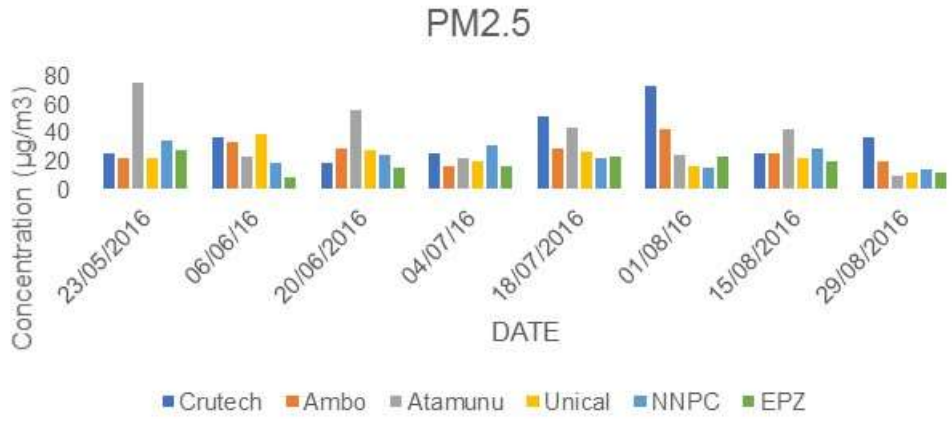

Figure 4. PM2.5 concentration plot.

standard on certain days of measurement. Figure 6 shows concentration plot for TSP. the diagram shows that most data taken were below the Nigerian National standard. It is only measurement at Crutech and NNPC stations that exceeded the Nigerian National standard. The highest mean concentration of $PM_{2.5}$ for the duration of the study was 37.2 µg/m^3, recorded at Atamunu station. For PM_{10}, it was 160 µg/m^3, recorded at Crutech station. For TSP it was 225.05 µg/m^3, recorded at Crutech station. This concentration is comparable to that measured in other places. According to Ikamaise et al. (2013), TSP maximum concentration measured in Calabar was 269 µg/m^3. According to Schwander et al. (2014), the concentration of $PM_{2.5}$ measured in Kampala, Uganda in a research carried out in 2013 was 103.7 µg/m^3 while PM_{10} was 208.1 µg/m^3. Box plots in Figures 7 to 9 are based on the statistical data on Table 2. The data carrying a superscript a represents $PM_{2.5}$, that carrying b represents PM_{10} and the one carrying c represents TSP. Figure 7 represents statistical data for $PM_{2.5}$. It can be seen from the figure that Atamunu station had the highest mean and median concentration. This makes the

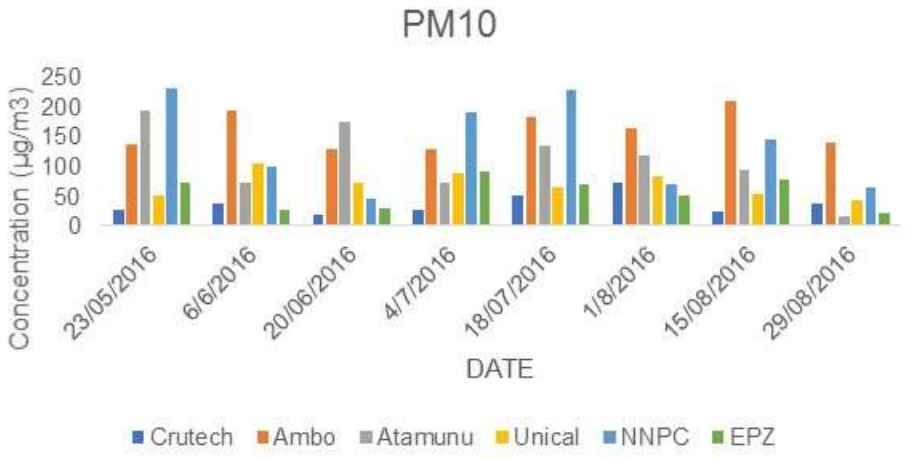

Figure 5. PM10 concentration plot.

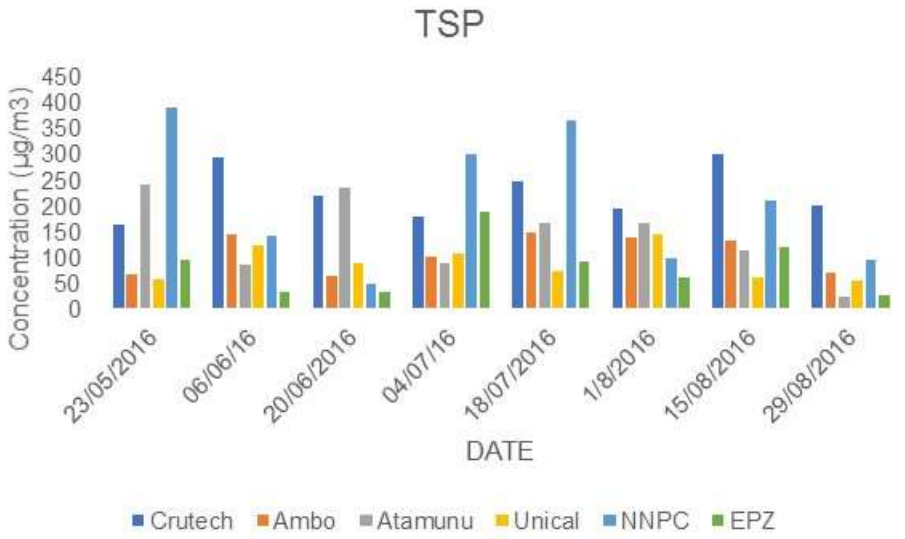

Figure 6. TSP concentration plot.

station the most polluted in terms of $PM_{2.5}$ concentration. If this plot is compared with that of the other station, it is glaring that Atamunu station had that greatest concentration range (22.88µg/m^3 – 47.17 µg/m^3). This means that 75% of the measured concentration fell above the 20 µg/m^3 mark. The total concentration of $PM_{2.5}$ measured from the other stations was below 50% concentration of that measured at Atamunu Station. The safest place in Calabar in terms of $PM_{2.5}$ pollution is EPZ tank farm station. It has the least mean concentration of $PM_{2.5}$ and the least median concentration. Figure 8 represents the statistical data for PM_{10}. It can be seen in the figure that NNPC tank farm station has the highest mean concentration of PM_{10}. NNPC station also has the highest spread of concentration with75% of measured concentration within the range of 50µg/m^3 - 250µg/m^3. The most polluted station in terms of PM_{10} is NNPC tank farm station. While the least polluted station is Crutech gate station with the least mean concentration and the least median concentration. Figure 9 shows the statistical data for

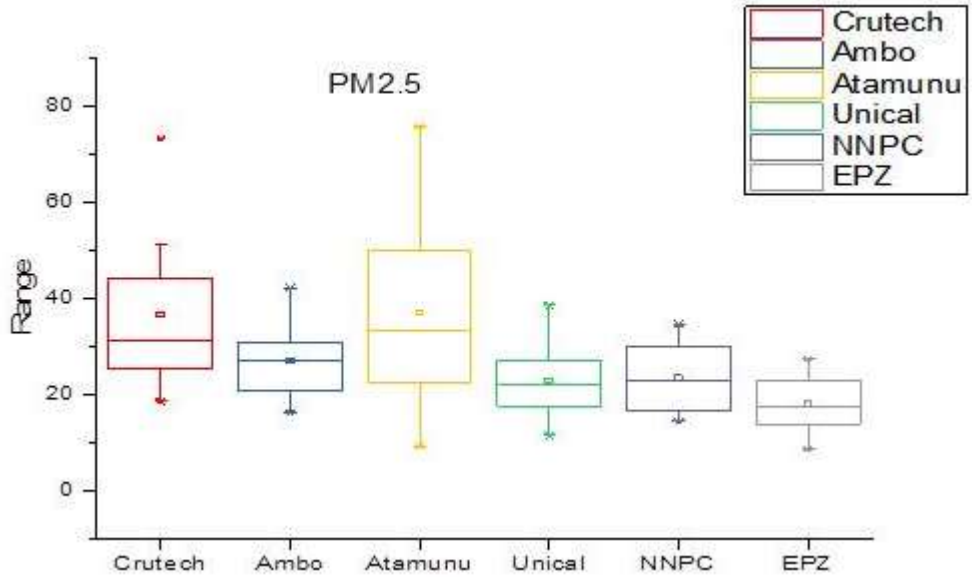

Figure 7. Box plots showing concentration of PM2.5 for the different locations.

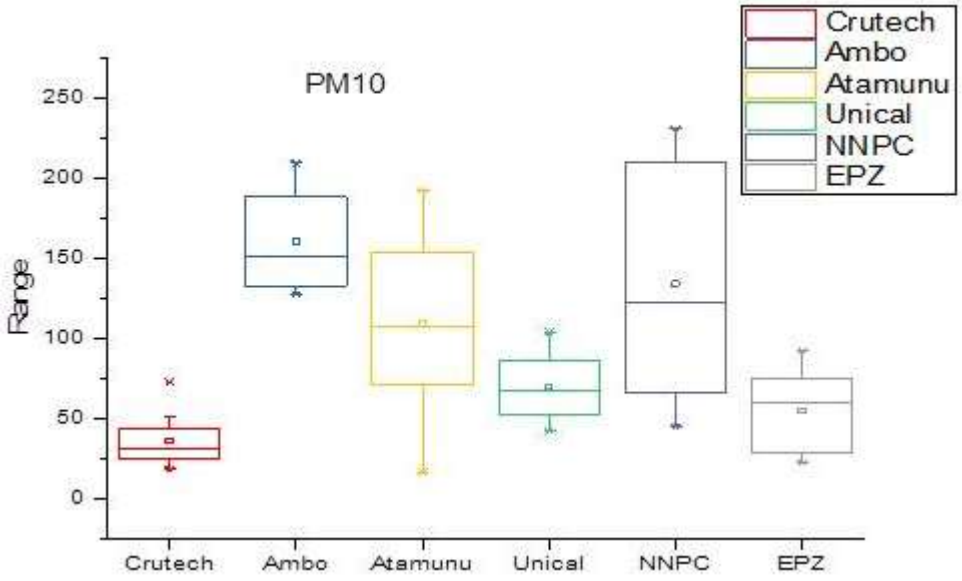

Figure 8. Box plots showing concentration of PM10 for the different locations.

TSP. It can be seen from the plot that Crutech gate station is the most polluted in terms of TSP. In Arnhem, Netherlands, in 2008, $PM_{2.5}$ was 114.8 µg/m^3, while PM_{10} was 78 µg/m^3 (Zuurbier et al., 2010). This is within the range measured during this research.

The diagram shows that the station recorded the highest median concentration making it the most polluted. Unical station is the least polluted in terms of TSP concentration. At NNPC station, about 50% of the measured concentration fell within 50µg/m^3 - 200µg/m^3. At Crutech gate station, 25% concentration fell between 150µg/m^3 - 200 µg/m^3. The median concentration is also above 200µg/m^3.

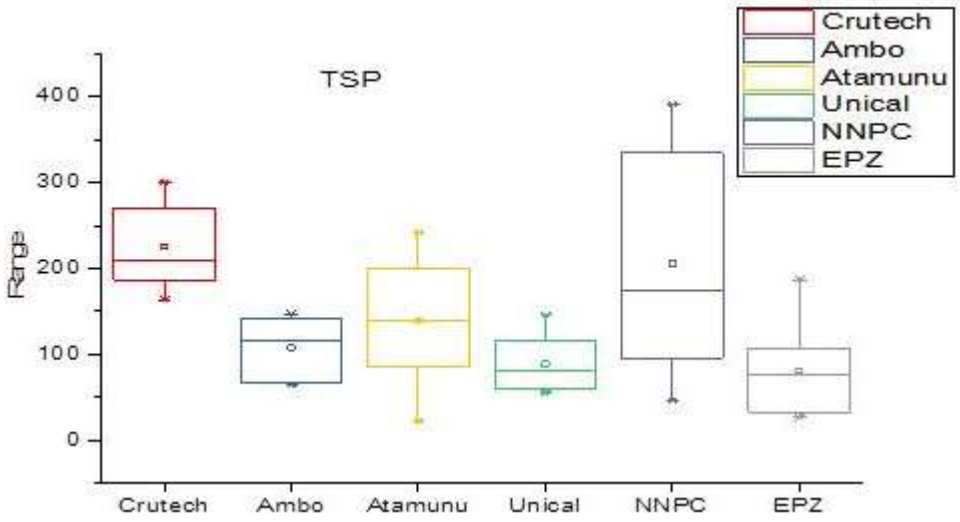

Figure 9. Box plots showing concentration of TSP for the different locations.

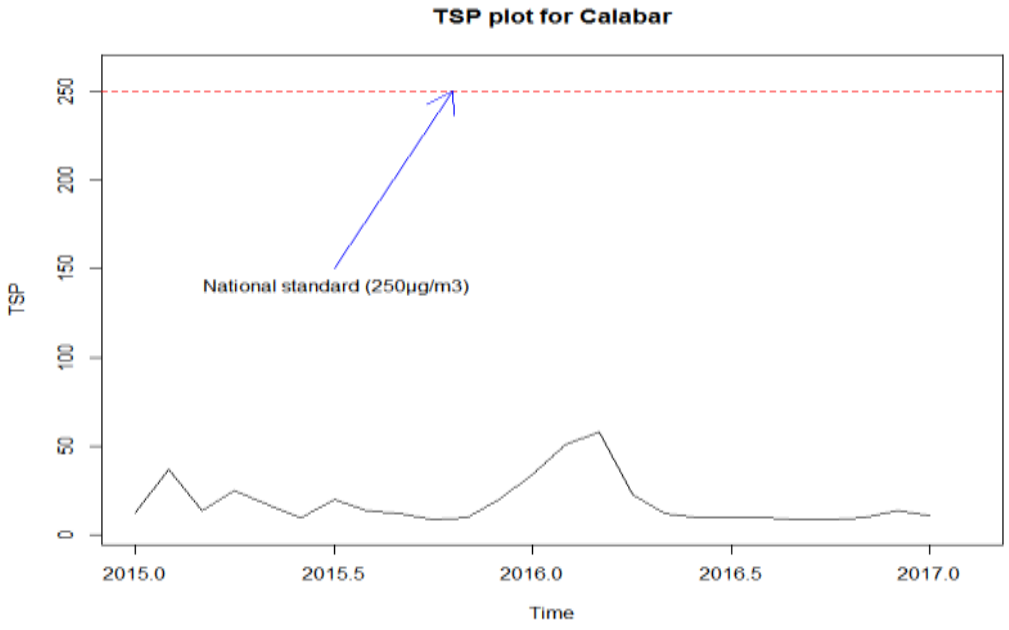

Figure 10. Tsp plot for Calabar location based on the AQM65 data.

Figure 10 shows time series plot of TSP as measured by the stationary AQM65 equipment stationed at the Unical main station. The plot shows that the concentration of TSP was high between January 2016 and March 2016. The overall concentration measured within the two years under consideration, the concentration of TSP was below the Nigerian national air quality standard. The red line in the figure shows the Nigerian national air quality standard (250µg/m^3).

Table 2. Statistical analysis for the different locations.

STATION	Minimum conc.	Maximum conc.	Mean	Median	1st quartile	3rd quartile
CRUTECH	[a]18.70 [b]16.70 [c]168.90	[a]73.20 [b]73.20 [c]300.4	[a]36.74 [b]36.74 [c]255.10	[a]31.25 [b]31.25 [c]210.30	[a]25.50 [b]25.50 [c]190.20	[a]40.77 [b]40.77 [c]259.70
AMBO MARKET	[a]16.30 [b]127.8 [c]64.80	[a]42.30 [b]209.4 [c]147.40	[a]27.10 [b]160.5 [c]108.11	[a]27.10 [b]151.8 [c]116.45	[a]21.27 [b]134.8 [c]68.83	[a]30.07 [b]185.7 [c]140.43
ATAMUNU	[a]9.40 [b]17.0 [c]22.60	[a]75.80 [b]192.60 [c]242.50	[a]37.20 [b]109.5 0 [c]139.71	[a]33.60 [b]107.25 [c]139.45	[a]22.88 [b]71.55 [c]87.42	[a]47.17 [b]143.82 [c]183.75
UNICAL	[a]11.60 [b]42.70 [c]55.40	[a]38.60 [b]104.10 [c]146.00	[a]23.04 [b]70.05 [c]89.04	[a]22.10 [b]68.00 [c]80.50	[a]18.48 [b]53.50 [c]60.40	[a]27.00 [b]85.10 [c]110.88
NNPC	[a]14.50 [b]45.20 [c]46.80	[a]34.70 [b]230.70 [c]391.10	[a]23.57 [b]134.3 9 [c]206.29	[a]23.05 [b]122.65 [c]175.30	[a]17.45 [b]68.72 [c]96.47	[a]29.52 [b]200.60 [c]318.07
EPZ	[a]8.80 [b]22.50 [c]27.00	[a]27.50 [b]92.60 [c]187.10	[a]18.26 [b]55.44 [c]80.79	[a]17.70 [b]60.05 [c]76.40	[a]19.85 [b]29.43 [c] 33.02	[a]23.05 [b]73.90 [c]11.28

[a]PM2.5 [b]PM10 [c]TSP

CONCLUSION

It has been concluded from this research that, Atamunu station is the most polluted site in Calabar in terms of $PM_{2.5}$ Pollution, while EPZ tank farm station is the cleanest in terms of $PM_{2.5}$. Ambo market is the most polluted in terms of PM_{10} pollution, while Crutech gate is the cleanest in terms of PM_{10}. Crutech gate is the most polluted in terms of TSP, while EPZ tank farm is the cleanest place in Calabar in terms of TSP. The measured concentrations of $PM_{2.5}$ and TSP were below the Nigerian national air quality standards. PM_{10} concentrations measured at Atamunu and NNPC tank farm were above the Nigerian national standards.

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