GEOSPATIAL ASSESSMENT OF SUSPENDED PARTICULATE MATTER (SPM2.5) FOOTPRINTS ACROSS DOMINANT LAND USES IN CALABAR METROPOLIS, NIGERIA

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ABSTRACT

*This study examined Suspended Particulate Matter, $SPM_{2.5}$ footprints in Calabar Metropolitan area using Geographic Information Systems (GIS) infrastructure. The area is a dynamic and sprawling city, comprising Calabar Municipality and Calabar South Local Government Areas, with diverse land uses. Data on the emission level of $SPM_{2.5}$ were sourced within the period of 6 months in both dry and wet seasons. The data logger used was the Crowcon Gasman. Point coordinates were collected using the Garmin GPSMap 60CSx device. An interpolation algorithm in (GIS) was employed to generate the composite map showing $SPM_{2.5}$ footprint for the metropolis. Relevant and related analytical techniques were also applied. Non-parametric statistics such as tables, graphs, charts, maps and standard deviation were also used to present the data in line with the study objectives. From the findings, F-ratio for both season and land use is significant for all the tested parameters (F-ratio for season is $F(1,3224)= 511.669$, at $p<0.05$, while for land use, $F(3,3224)=299.015$, at $p<0.05$). The interaction between seasons and land use (season * land use) for the parameters, $F(3, 3224) = 211.488$, $P<0.05$ is also significant. $SPM_{2.5}$ variability in Calabar Metropolis was found to be significant in relation to either land use types or seasons of the year. Based on the findings, mitigatory and control measures were recommended to ensure a sustainable, clean and green Calabar Metropolis.*

Key Words: *Geospatial, Footprints, Land uses, Pollution, Particulate Matter*

1. INTRODUCTION

Suspended Particulate Matter (SPM) is one of the major contaminants of air in urban areas worldwide. SPM comprises particles less than 10 µm in diameter suspended and floating in the atmospheric environment. Air particulates within 2 µm range in diameter, emanating from sources such as incinerators, boilers, and automobiles, may reach deeply into human lungs during respiration and ultimately cause respiratory diseases. SPM can also be produced by photochemical reactions of gaseous substances in the atmosphere (Kuwata, Nishikawa, 2005)

In most West African cities such as Lagos, Nigeria, as well as other major cities of the advanced world, outdoor ambient air pollution has been identified as a major threat to human health (Boko and Joachim, 2003; Chai, Qian, and Feng 2004; Nku, Peters, and Eshiet, 2005; Wiwanitkit, Suwansaksri, and Soorgarun, 2005; Rojas-Rueda, de Nazzelle, and Tainio, 2011; Obiefuna 2019; WHO 2020; Obiefuna, Njar and Bisong 2021a; Obiefuna, Inah, Iwuanyanwu and Eteng 2022; Imoke, Michael, Uquetan, Obiefuna, Asor and Egbonyi 2023). Poor ambient air quality is capable of negatively altering the average life span of individuals, communities or even nations that are constantly being exposed.

According to global estimates by the United Nations Environment Programme (UNEP), a lot of people amounting to over one billion breathe unhealthy air (Jansen, Qian, and Wojciechowska-Shibuya, 2002)

Finally, since economic activities constitute or result to pollution of varying degrees, it is pertinent that various land uses in Nigeria, which represent diverse economic activities, be scrutinized for various pollutants to ensure that they conform to acceptable standards, otherwise, the people and property would be endangered.

This research geospatially examined SMP2.5 footprints across dominant land uses in Calabar Metropolitan area.

2. The Problematic

$SPM_{2.5}$ is a silent killer due to its particle size. It causes cancer, irritation and other respiratory-related issues in humans. According to Stephen and Sundar (2011), PM2.5 is said to be a causal agent for cancer, heart or respiratory disease. Despite this, there appears to be unrelenting sporadic localization and distribution of various forms of economic activities and other informal enterprises that generate a high volume of SPM in Calabar Metropolis. All these ultimately give rise to dust effluents which must be measured, mapped and planned for remediation to be possible.

SPM has been scantily studied both independently as a single parameter, as well as with other parameters in the study area but no serious effort was devoted to geospatially visualizing its distribution. Lack of visually projected information about SPM would hamper certain developmental strides and decisions. For example, air quality status taken over a period of time and analyzed graphically would give information on the level of visibility and effluents that are attainable at certain locations and given periods (Obiefuna, Inah, Atsa and Etim, 2021b; Obiefuna and Uttah, 2023). This information would be of immense benefit during transportation planning.

3. Aim and Objectives of the Study

This research assessed suspended particulate matter (Spm2.5) footprints in Calabar Metropolis, Nigeria, in relation to existing dominant land use elements. It also generated a spatial and temporal-based air quality footprint map depicting suspended particulates distribution in the region, using the GIS infrastructure.

4. The Study Area

The study area is Calabar Metropolis, which is the capital city of Cross River State (FIG.1). Calabar is located between longitudes 8° 18' and $8^{0}25''$ East of the Greenwich meridian and latitudes 4°55' and $5^{0}10'$ North of the Equator. It is sandwiched between the Great Kwa River to the East and the Calabar River to the west. Calabar Metropolis, comprising of Calabar Municipality and Calabar South Local Government Areas has a total land area of 1480sqkms. Calabar is bounded to the North by Odukpani Local Government Area, and to the East by Akpabuyo Local Government Area.

5. RESEARCH METHODOLOGY

The study relied on primary data on particulate distribution across various land uses as well as data on its seasonality variation in Calabar Metropolis, Nigeria. Data were expressed in parts per million (ppm) scale.

Data were acquired using several automated data loggers named Crowcon Gasman and a Garmin GPSMap. The dataset included logged figures on the level of pollutants occasioned by suspended particulate matter from various locations within identified land uses as well as the GPS coordinates for the locations.

SPM2.5 data collection was carried out at each selected location within a land use using a real-time, automated air quality monitor, mounted on a ground-based platform/tripod, or held at a height of range of between 1.5 and 2.0 meters from the ground. Data readings were made once in the afternoon between 12 noon and 12.30 pm. This represents the peak period when economic activities are at their optimum. The duration of data collection lasted for four months. In the rainy (wet) season, readings were taken between July and August, while in the dry season, readings were taken between November and December.

$PM_{2.5}$ is said to be a causal agent for cancer, heart or respiratory disease (Stephen and Sundar, 2011)

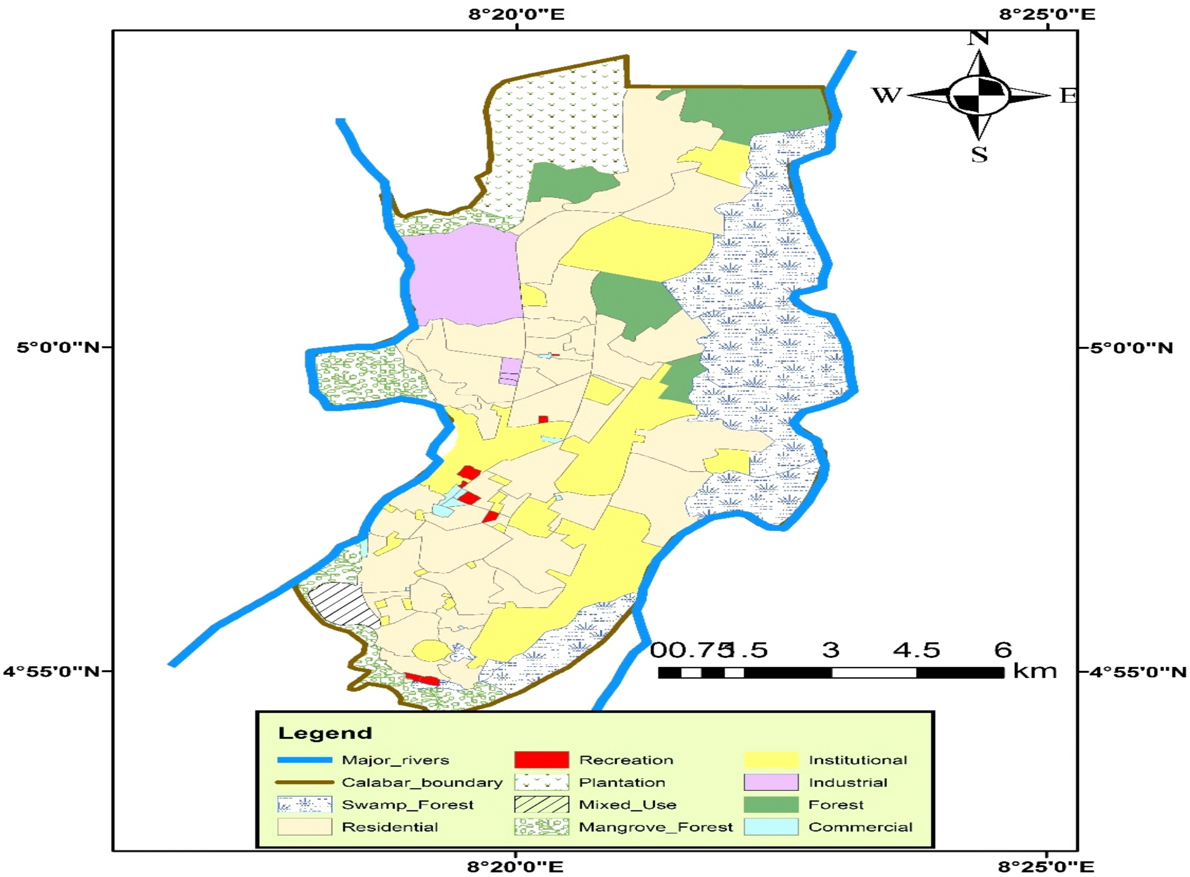

FIG.1: Land use map of Calabar Metropolis showing the study area.
Source: Obiefuna, Inah, Atsa and Etim (2021b)

Stratification and randomization were employed to group and randomly select points from each land use for proper representation. Though a total of 24 locations were identified for the transportation land use, 7 were selected. On this land use, data were acquired along road nodes on major road networks, roundabouts and parks. For industrial land use, data were acquired from both the minor road intersections/junctions within the zone as well as 10 metres from the pollution sources. A total of 18 locations were identified in the industrial land use, while five (5) locations were selected. For commercial land use, data were acquired from the pollution sources after having identified them. 22 locations were identified while 7 locations were selected. With regards to the residential neighbourhood, data were acquired from minor road intersections and other emission points. A total of 23 locations were identified while seven (7) locations were also selected. Presented below is Table 1, which shows a total of 26 sample points representing 30 per cent of the total observed points from all land uses. This decision for 30 per cent selection was based on Udofia (2011), which states that a sample fraction of 10 per cent is deemed adequate as no serious research can progress with a sample fraction less than 10 per cent. This means that the 30 per cent sample fraction employed in this research is very adequate**.** The selection was done using a row-by-column digital random number generator. The sample points have been depicted (FIG. 2).

Sourced data were subjected to geospatial and statistical analytical manipulations using GIS, and descriptive statistics. The output was in averages, tables, charts, graphs and composite maps showing SPM footprints for the study area.

6. Result

Table 1 shows the descriptive statistics for $SPM_{2.5}$ in terms of the mean and standard deviation for the wet season, dry season and total over the various land uses. For example, the mean value of $SPM_{2.5}$ for industrial land use is 2.6471 in the wet season and 3.9073 in the dry season. From the results, the F-ratio for season is $F(1,3224) = 511.669$, $P<0.05$ is significant. Similarly, for land use, $F(3,3224) = 299.015$, $P<0.05$ is significant. For the interaction between seasons and land use (season * landuse), $F(3, 3224) = 211.488$, $P<0.05$ is also significant. This shows that $SPM_{2.5}$ is higher in the dry season than in the wet season. Similarly, observations can be made on $SPM_{2.5}$ for other land uses. Table 2 shows the test of between-subject effects with $SPM_{2.5}$ as the variable of interest over the various land uses and seasons of the year. Fig. 3 depicts the mean $SPM_{2.5}$ level for the study locations.

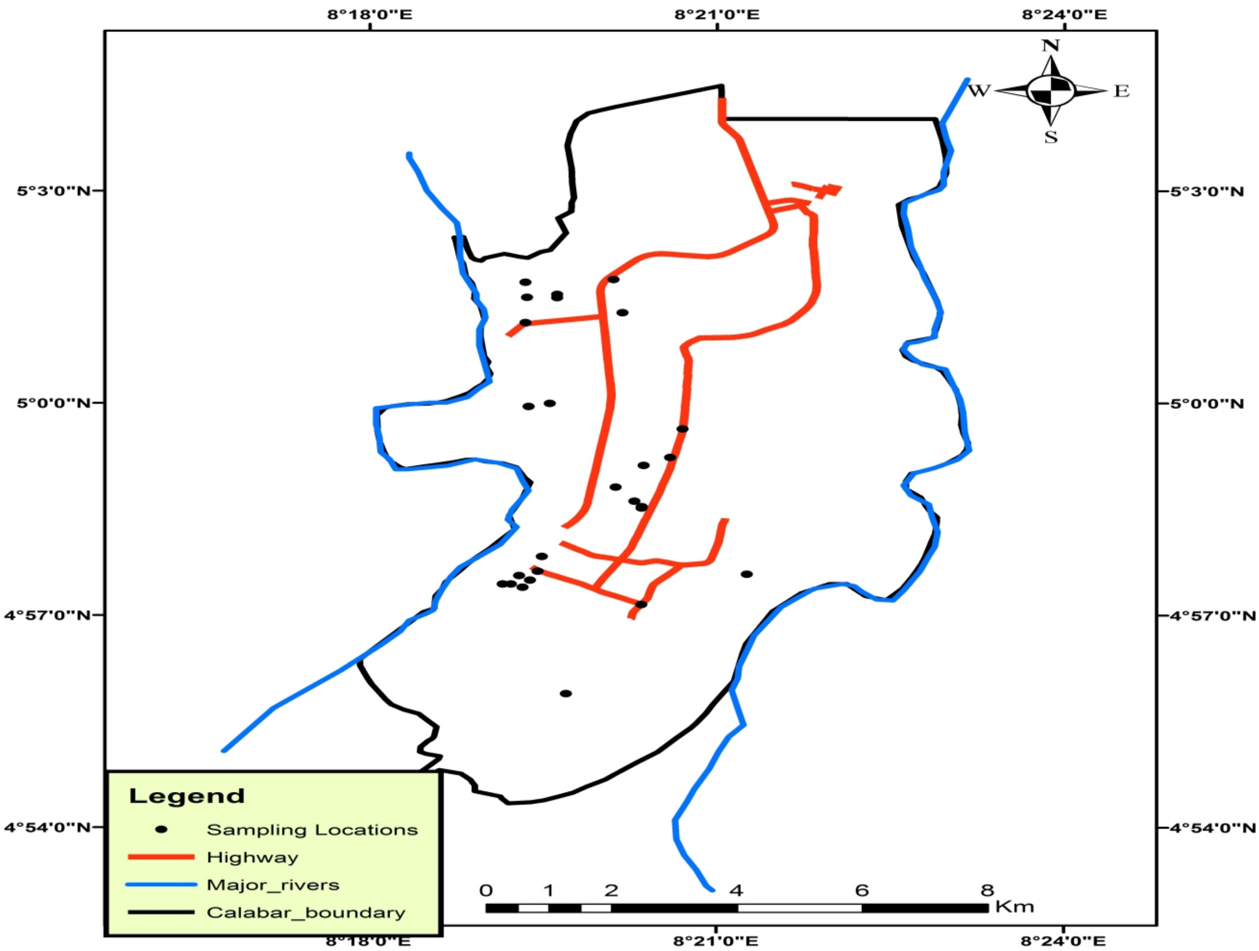

FIG.2: Sampled locations across land uses in Calabar Metropolis
Source: Author`s fieldwork

TABLE 1
Descriptive statistics for the analysis of SPM 2.5 across land uses

Season	Land use	Mean	Std. Deviation	N
Wet season	Industrial	2.6471	.57872	310
	transportation	3.4923	.67118	434
	Commercial	3.3060	.62331	434
	Residential	2.1045	.50544	434
	Total	2.9060	.82468	1612
dry season	Industrial	3.9073	1.14172	305
	transportation	2.9024	1.40953	427
	Commercial	4.3394	.76751	427
	Residential	3.1191	.67090	427
	Total	3.5409	1.19109	1586
Total	Industrial	3.2772	1.10252	620
	transportation	3.1974	1.14207	868
	Commercial	3.8227	.86920	868
	Residential	2.6118	.78103	868
	Total	3.2234	1.07232	3224

Dependent Variable: $SPM_{2.5}$

Source: Analysis by the Author, 2020.

TABLE 2
Tests of Between-Subjects Effects for SPM $_{2.5}$

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1415.630[a]	7	202.233	283.957	.000	.382
Intercept	32874.118	1	32874.118	46158.854	.000	.935
Season	364.408	1	364.408	511.669	.000	.137
Land use	638.870	3	212.957	299.015	.000	.218
Season * Land use	451.862	3	150.621	211.488	.000	.165
Error	2290.420	3216	.712			
Total	37204.778	3198				
Corrected Total	3706.050	3197				

a. R Squared = .382 (Adjusted R Squared = .381). Dependent Variable: $SPM_{2.5}$

Source: Analysis by the Author, 2020.

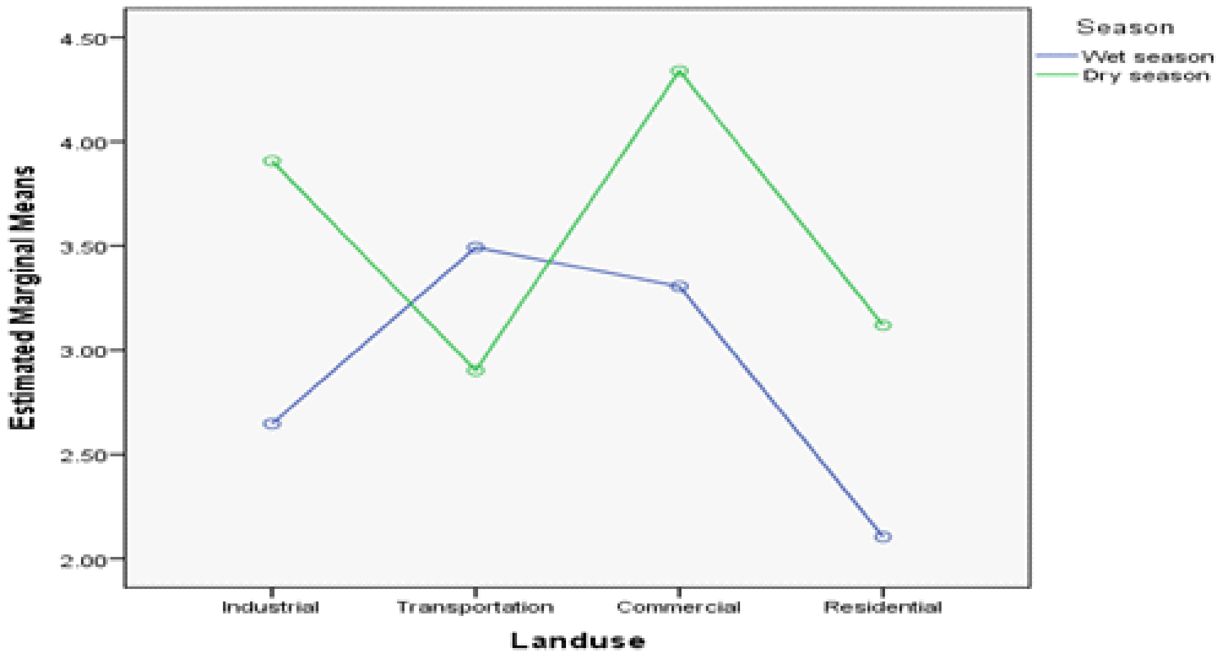

FIG.3 Mean of $SPM_{2.5}$ across the various land uses.

Source: Analysis by the Author, 2020.

7. Discussion of Findings

From findings, air quality ($SPM_{2.5}$) in Calabar Metropolis significantly varied in relation to either land use type or season of the year. The land uses that cause significant variation are the commercial and residential. This has been depicted in the choropleth (FIG.4), which indicates the level of SPM concentration over the metropolis. From the footprint map, the concentration of SPM is dense in most parts of the built-up area, particularly along the transportation, commercial and industrial land uses. The peripheral agricultural, open spaces, as well as non-built-up areas particularly in green shades, have been identified to be low in $SPM_{2.5}$.

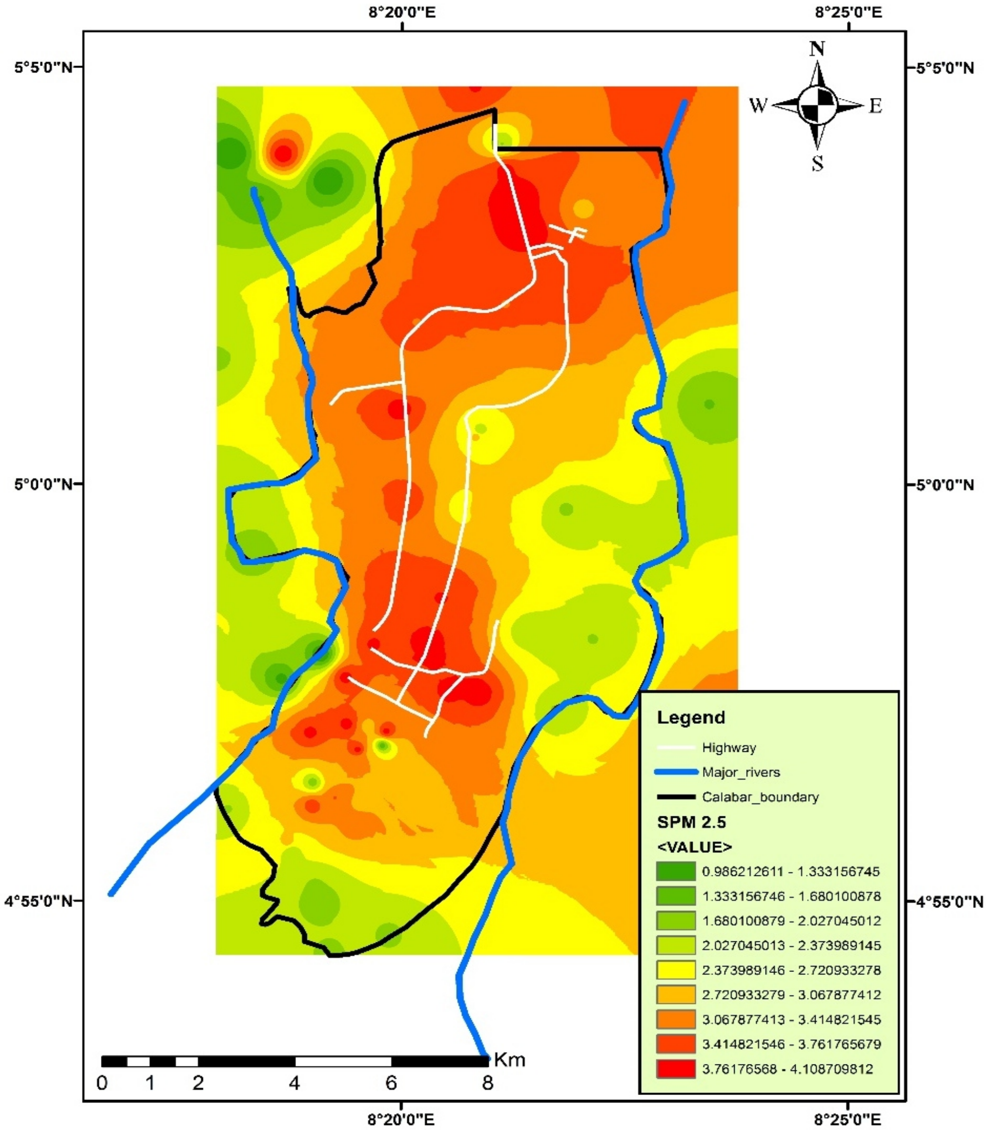

Plate 1a

Plate 1b

Plate 1a. Generators as point sources of pollution. Source: by the author, 2021
Plate 1b. Automobiles as line sources of pollution, Source: by the author, 2021

8. Conclusion

This study has been able to geospatially assess PM2.5 footprints across the dominant landuses in Calabar Metropolis. SPM2.5 variability in the Metropolis was found to be significant in relation to either land use types or seasons of the year. Composite map showing the distribution has also been developed and generated. Environmental pollution occasioned by SPM is volatile to human health and therefore, should be minimized through concerned efforts and constant monitoring.

9. Recommendations

Based on the findings, certain mitigatory measures are therefore recommended to ensure a sustainable, clean and green Calabar Metropolis. these include:

1. SPM, being volatile to human health, should be minimized through concerned efforts and constant monitoring. Besides, residential zones should be exclusively maintained to avoid encroachment of incompatible uses which could lead to pollution and blight. Residential zones that have already been encroached, depending on the form of encroachment, should be reclaimed. For example, multiple exit routes should be closed to discourage motorists from using such alternative routes to other destinations thereby causing heavy traffic and pollution.

2. There is need for a periodic and real-time monitoring and envisioning of air quality status to ensure adequate and strict compliance with standards. This would help in the enforcement of related codes once violated. It would be very helpful in the continuous acquisition of more robust datasets that could be used in the pre-emptive planning of the metropolis in favour of the Clean Air Act. Finally, more comprehensive research which would cut across the 12 calendar months should be undertaken on this theme.

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