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Atmospheric Concentration of Particulate Pollutants and its Implications for Respiratory Health Hazard Management in Port Harcourt Metropolis, Nigeria

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Abstract
Human impacts on the atmosphere have been notorious for their large emissions of trace gases and particulate matter into the atmosphere. Recently, there is growing awareness in Nigeria of the adverse effects of air pollution on health and environment especially that of Suspended particulate matter. This paper examined the spatial and seasonal concentrations of particulate pollutants and its health implications for the Port Harcourt city residence. Using standard equipments data on weekly concentration of particulates were obtained for the wet, transition and dry seasons. Findings showed that the percentage seasonal weekly contribution of PM_{10} by the respective landuse indicate that the industrial areas had the peak value of 65.14%, 29.51% and 16.92% during the dry, wet and transition period respectively. The transport areas accounted for 12.43%, 14.91% and 7.34% during the transition, dry and wet seasons respectively. For the High Density Residential areas, the dry, transition and wet seasons accounted for 14.04%, 12.67% and 7.34% respectively. Finding further showed that the risk of respiratory related diseases is expected to be higher among high density residential areas of Woji, Nkpogu, Nchia, Aleto, Akpojo, Alesa, Ogonigba, Okrika main land, and Elelenwo sandwiched between the Trans-Amadi and Eleme industrial areas that are located down-wind of the city. Member of the public who are vulnerable to these diseases should stay clear from these areas. It advocates regular monitoring of particulates in order to reduce the disease burden.
Keywords: Particulates pollutants, Respiratory diseases, Landuse, Seasonal, Port Harcourt.

1. Introduction

The cities of the world are today facing serious air quality problems which tend to threaten human existence (Molina and Molina, 2004). This problem is becoming acute as cities become globalized and the space of economic activities increase. Thus concerted efforts are required to solve this problem.

The problems of air pollution in urban areas have been known for millennia but until recently attempts to combat them were ambiguous, scattered and ineffective (Fenger, 2009). Initially the problem was seen as that of the developed industrialized nations of the world but recent concerns and findings have shown that developing countries, in the process of industrial growth, are facing similar situation or even worst, which developed countries had in the 1950s (Fenger, 2009). With the increase of industrial activities all over the world the scale of urban pollution has increased both in time and extent, and now threaten nature and mankind over large areas and ultimately over the entire earth.

It has long been recognized that the atmosphere plays a significant role in international problem of environmental dispersion process of air pollution concentrations and transport caused by different emission sources, the seasonal and spatial variation of the PM_{10} has however not been given due and sustained attention especially in Nigeria and in Port Harcourt metropolis. Port Harcourt houses over 80% of hydrocarbon industry in Nigeria. Its intense industrial and socio-economic activities make it a rapidly developing city in the tropics. There are great needs for characterization of seasonal and long-term variations in PM_{10} concentrations as well as better understanding of the governing effects of meteorology on its concentration and dispersion.

2. The Problem

The existing literature suggests that air pollutants and indeed PM_{10} could contribute to increase in hospital admission, lead to absence from work and school, increase in mortality rate (see Kunzli *et al,* 2000; Cifuentes *et al*, 2001; COMEAP, 2001; Giri *et al*; 2006; Wang and Zhao, 2008; Hopke, 2009) For animals, there are the problems of mottled teeth and condition of the joints known as exostosis leading to lameness and ultimate death (Han and Naeher; 2006). In the case of atmospheric properties, air pollutants causes visibility reduction which may lead to safety hazards, fog formation and precipitation, solar radiation reduction and alteration in temperatures and wind distribution (see Jacobson, 2001; Rosenfeld, 2002; Chow *et al*.,2002; Watson 2002a,b; Cao *et al* 2004). Vegetations are not also exempted from the impact of mostly gaseous pollutants; it causes destruction of the chlorophyll and the destruction of photosynthetic activity which untimely leads to death of plant (Qi, *et al*.2000). Different landuse types, seasons and meteorological conditions are associated with different pollutant generation, concentration and dispersion respectively. Indicators of spatial variation in air pollution have been provided on the basis of land uses, technology, urban – rural dichotomy and regional transportation system (EPA, 2001). Regional development patterns are usually heterogeneous, hence spatial distribution of ambient air quality. Apart from this, particulates can be transported from one land use to another, depending on the topography, wind and pressure gradients. Air pollution in Nigeria is not new and several scholars have attempted to examine the concentration of pollutants and their effect on our environment. Some of the studies are those of Ede (1999), Ossai *et al;*(1999), Okecha (2000), Efe (2005, 2006 and 2008), Awofolu (2004), Akeredolu *et al*. (1994) and Akani (2007). From the available literature, it is obvious that there is dearth of empirical analysis of air quality associated with PM_{10} which are widespread within the region. The spatial pattern of air pollutants can perforce be attributed to the differential land uses pattern. Within the Port Harcourt metropolis, several landuse types exist with surrounding rural areas. The urban landuses are not homogeneously concentrated rather residential landuses are sandwiched in-between industrial and commercial landuse or vice verse. Arising from the above, it becomes very necessary to monitor the concentration of particulate pollutants (PM_{10}), especially because of their health implications, for the city residents and the entire Niger Delta region.

3. The study area

Port Harcourt is the capital of Rivers State. It is the main city in the state and has one of the largest seaport in the Niger Delta region of Nigeria. It is the hub of industrial, commercial, administration and other activities in the state. The city lies between latitude 0^0 23^1-7^0 30^1E and 5^0 45^1-40^0 15^1N. It covers an estimated area of 1811.6 square kilometers. The city is bounded in the north by Imo and Abia States east by Akwa-Ibom State, West by Bayelsa State and south by the Atlantic Ocean. Weather systems particularly rainfall in Nigeria are primarily a result of the interplay between two major pressure and wind systems. These are the two dynamically generated sub-tropical high pressure cells centered over Azores Archipelago (off the west coast of North Africa) and St. Hellena Islands (off the coast of Namibia). These high pressure centers (or anticyclones) which are permanent generate and drive respectively the North-East trade winds and the South-West winds, which are the northward extension of the re-curved South-East trade winds of the South Atlantic Ocean. The major rainfall controls over Nigeria are, apart from the seasonal location of the ITD, the distance inland from the coast and relief. Generally, rainfall over Nigeria diminishes with increasing distance from the moisture source in the South Atlantic. Thus, coastal areas like the Port Harcourt region, receive heavier and more persistent rainfall because the South-West wind is strong. The strength of the air mass is reduced as it penetrates inland. This also affects temperature. Ascent of air over high ground produces cooling which can lead to condensation and precipitation. This phenomenon described as orography, does not control any weather system in the region in that the area is devoid of any high lands. Pollution in the atmospheric medium travels the farthest and industrial emissions are one of the most important sources of air pollution. The implications of the location pattern of industries for pollution are many. The dominant airmass over Port Harcourt is the South West Trade Wind. Detailed wind flow characteristics over the city include periodic doses of emission from the major industrial locations around the city. The incidence of land breeze, as well as, the Harmattan factor actually transfers emissions into the city (Ede, 1999).

4. Methodology

Air quality was measured in the stations stated below reflecting the major and different land use types in the city. . The eTrex Venture Garmin GPS which display transect movements: waypoints, latitude and longitude grids was used to determine the X and Y coordinates of selected monitoring sites .The Kestel 400 version 3.00; hand held weather tracker was used to obtain the elevation above mean sea level of each sample station. The X, Y coordinates and the elevation (Z) data was used to produce a map showing area of equal concentrations of pollutants in the city (referred to as Isopleths map). The collection of air quality and meteorological data for this study commenced from 2nd August to 18th September, 2010 reflecting the wet season; transition period of October 4th to November 20th, 2010 and dry season period of January 3rd to February 19th 2011. The choice of these seasons is based on rainfall distribution of Port Harcourt. This covered about 126 days (42 days each of the three seasons) The transition period of rainfall represents the period when rainfall begins to recede giving way to the dry season. It is also a period between the wet season and the dry season. These steps were taken in order to capture the fluctuations in pollutant concentrations in all the stations for all the seasons. In order to select the sample points which will serve as air quality monitoring stations, a land use map of the study area with the scale 1:1,000 was gridded 500m x 500m. All the squares were coded in their respective land use type and selection was made without replacement to obtain two monitoring stations representing a specific landuse to obtain twelve stations of the five major land use types in the city of Port Harcourt. This has to be done in order to give all the areas the equal and non zero chance of been selected for the study.

The table 1 below shows areas which constitute the major land use areas and their co-ordinates where monitoring station was cited in order to achieve the objectives of the study. For all the land use types, effort was made to identify the general direction of wind. This is to enable us identify the down-wind and up-wind direction to enhance the quality and reliability of the data that was collected.

Table 1: Monitoring stations and their coordinates.

Landuse typology	Stations	Latitudes (^{0}N)	Longitudes (^{0}E)
Industrial	Eleme	$4^0 47^1 29.6^{11}$	$7^0 6^1 46.3^{11}$
	Trans-Amadi	$4^0 48^1 18.7^{11}$	$7^0 1^1 51.8^{11}$
High density residential	Diobu	$4^0 47^1 32.8^{11}$	$6^0 59^1 23^{11}$
	Rumuagholu	$4^0 52^1 25.3^{11}$	$6^0 59^1 15.2^{11}$
Low density residential	GRA	$4^0 48^1 26.3^{11}$	$6^0 59^1 52^{11}$
	Abuloma housing estate	$4^0 46^1 56.5^{11}$	$7^0 2^1 46.7^{11}$
Commercial	Mile III Market	$4^0 48^1 27.8^{11}$	$6^0 59^1 10.6^{11}$
	Creek road market	$4^0 45^1 31^{11}$	$7^0 1^1 37.5^{11}$
Transport	PH-Aba exprees way	$4^0 48^1 19.2^{11}$	$7^0 0^1 31.9^{11}$
	Ikwerre road	$4^0 52^1 2.1^{11}$	$6^0 59^1 50.2^{11}$
	PH Int'l Airport	$5^0 0^1 52.5^{11}$	$6^0 57^1 0.9^{11}$
Rural	Aluu	$4^0 56^1 9.3^{11}$	$6^0 56^1 54.7^{11}$
	Egbelu-akami	$4^0 50^1 56.1^{11}$	$6^0 57^1 0.3^{11}$

Source: Author's field survey, 2011.

5. Result and Discussion of findings.

Findings showed that the mean weekly spatial variation in the concentration of PM_{10} in Port Harcourt (fig. 1) was highest that the industrial land use area. It had the highest Maximum value of 1525.08Mg/m^3 during the dry season in week 2 and a minimum value of 27µg/m^3 in week 6 during the wet season; rural areas had 322.8 µg/m^3 as maximum value in week a during the dry season; High density residential area (HDR) has a maximum value of 322.3 µg/m^3 in week 6 during the dry season and 22 µg/m^3 as its minimum value in week 1 during the wet season; transport land use area has a PM_{10} maximum value of 413.7 µg/m^3 in week 1 during the dry season and minimum value of 10.16 µg/m^3 in week 1 during the wet season. The low density residential land use areas (LDR) had a low concentration of PM_{10} with a minimum value of 13.16 µg/m^3 in week 1 during the wet season and maximum value of 282 µg/m^3 in week 5 during the dry season. The reason for this result it because of the presence of heavy industrial activities especially at the Eleme industrial Zone which houses the Eleme Petro-Chemical Plants, Port Harcourt Refinery, Onne Oil and Gas Free Zone, The National Fertilizer Company amongst others. These industries emit volumes of Particulate Matters into the urban canopy of Port Harcourt. The study further revealed that the atmosphere loading of PM_{10} was recorded at 5,144,305 µg/m^3 during the transition period in Port Harcourt. With the industrial areas having a the highest value of 416.05 µg/m^3 and the low density residential land use areas (LDR) with the lowest mean value of 130.65 µg/m^3 and rural areas having a value of 146.21 µg/m^3 higher than the low residential land use areas. The graph showed that the highest concentration of PM_{10} recorded on the week 2 with a value of 1525.08µg/m^3 during the dry season and 44.8µg/m^3 during the wet season at the industrial land use areas. The concentration of PM_{10} in all the land use areas revealed that a marked difference exist among all the areas. This is evident in the variations of mean weekly concentration of PM_{10}. The first week of the dry season revealed that the industrial land use area had mean value of 602.25µg/m^3 during the dry season, followed by the commercial land use areas with a mean PM_{10} value of 524.3µg/m^3 during the dry season; at the transport land use areas with a value of 413.7µg/m^3, High density residential areas (HDR) value was put at 299.4µg/m^3 all during the dry season. At the rural area, PM_{10} value was 301.16µg/m^3 during the dry season. The analysis above showed that the highest value of PM_{10} concentration was observed at the industrial land use areas in the city during the dry season.

The second week further revealed that PM_{10} concentration varied from 1525µg/m^3 (dry season) at the industrial land use areas to 477.33µg/m^3 (dry season), at the commercial land use areas. The value of PM_{10} was reduced to 24.25µg/m^3 (wet season) at the rural areas. At the high density and low density residential areas, the mean value of PM_{10} was 279.75µg/m^3, 187.83µg/m^3 and 36.16µg/m^3 for the dry, transition and wet seasons respectively. Similarly week there showed that the highest concentration of PM_{10} with a value of 549.8µg/m^3 was observed at the commercial areas during the dry season, followed by the industrial area during the dry season with a PM_{10} value of 522.8µg/m^3. The value of PM_{10} was 307.66µg/m^3, 169.29µg/m^3 and 46.25µg/m^3 for the dry, transition and wet seasons respectively at the transport land use areas. But at the rural areas, the concentration of PM_{10} was remarkably low which varies between 232.1µg/m^3 in the dry season to 185.5µg/m^3 during the transition period and 50.25µg/m^3 during the wet season. Low density residential areas had the values of PM_{10} ranging between 248.3µg/m^3, 124.25µg/m^3 and 42.91µg/m^3 during the dry, transition and wet seasons respectively. At the high density residential areas, the concentration high as it was observed that PM_{10} had a concentration of 610.158µg/m^3 respectively. Week four revealed again that the activities in the industrial areas continue to keep PM_{10} concentration high as it was observed that PM_{10} had a concentration of 610.158µg/m^3, 410.16µg/m^3 and

23.54µg/m^3 during the dry, transition and wet seasons respectively. For the commercial areas, the values vary between 380.9µg/m^3 (dry season), 100.06µg/m^3 (transition) and 22.08µg/m^3 (wet season). High density residential area, had 300.1µg/m^3 (dry season), 121µg/m^3 (transition) and 22.08µg/m^3 (wet season). At the low density residential areas, the dry season had 252.5µg/m^3, transition had 78µg/m^3 and wet season value was 23.54µg/m^3 which has remained low. And rural areas had 322.8 µg/m^3 (dry season), 104.5 µg/m^3 (transition) and 22.16 µg/m^3 (wet season0.

It was revealed in week five that the industrial area still maintained the lead in the concentration of PM_{10} with the value of 614.5µg/m^3 (dry season), 587 µg/m^3 (transition) and 37.5 µg/m^3 (wet season). This was followed by the transport land use area with values ranging between 505.8µg/m^3, transport with a value of 389.1µg/m^3, low density residential (282.7 µg/m^3), high density residential areas with a value of 268.2 µg/m^3 and rural areas had a mean weekly average of 261.9 µg/m^3, all during the dry season. The lowest concentration of PM_{10} was observed at week five at the low density residential area during the wet season with a value of 22.16 µg/m^3, followed the rural with a value of 34.9 µg/m^3. For the transition period, the maximum value was observed industrial area with a value of 587µg/m^3, and the minimum value recorded at rural areas with a value of 149.41µg/m^3.

Week six revealed that high variation in the concentration of PM_{10} was observed during the dry season at the industrial areas with a value of 506.9µg/m^3 and the minimum recorded at low density residential area with a value of 244.5µg/m^3.

The transport areas had a value of 332µg/m^3, at the high density residential, rural; and low density residential areas the values aware 322µg/m^3, 277.3µg/m^3, and 244.5 µg/m^3 respectively during the dry season. For the transition period, the transport, HDR, rural, LDR, industrial and commercial areas, the value of PM_{10} was 180.41µg/m^3 184.75µg/m^3, 191.25µg/m^3, 144.5µg/m^3, 493.75µg/m^3 and 221.33µg/m^3 respectively. During the wet season, the transport, HDR, rural, LDR, industrial and commercial areas, had PM_{10} was values of 54.75µg/m^3, 27.5µg/m^3, 51.5µg/m^3, 21.91µg/m^3, 360µg/m^3, and 22.45µg/m^3 respectively. This result further revealed that the activities in the industrial areas and the commercial areas which include aluminum smelting, wood work, metal work and construction especially at the industrial area led to the increase in the atmosphere loading of PM_{10} over the atmosphere of the city of Port Harcourt. But for the commercial areas the increase in road constructional activities within the period of collective of this date led to this high concentration of PM_{10} in the city.

The concentration of PM_{10} on the seventh week as shown in fig.1 further revealed that PM_{10} value had a highest peak at the commercial areas with a value of 380.5µg/m^3 during the dry season. This is followed by the industrial areas with a value of 378.5µg/m^3, for the transport land use, the value of PM_{10} was put at 336.3 g/m^3, high density 284.4µg/m^3; rural, 195.1µg/m^3; low density residential, 264.5µg/m^3. For the transition period, the value of PM_{10} for the transport, HDR, rural, LDR, industrial and commercial land use areas were 145.66µg/m^3, 159.16µg/m^3, 116µg/m^3, 105.08µg/m^3, 294µg/m^3 and 243.25µg/m^3 respectively. But during the wet season the values were 26.08µg/m^3, 61.7µg/m^3, 24.5µg/m^3, 26.8µg/m^3, 446.9µg/m^3 and 27.0µg/m^3 respectively for the transport, HDR, rural, LDR, industrial and commercial land use areas. The GIS map of the spatial and seasonal variation in the concentration of PM_{10} (fig 2, 3 and 4) are shown below.

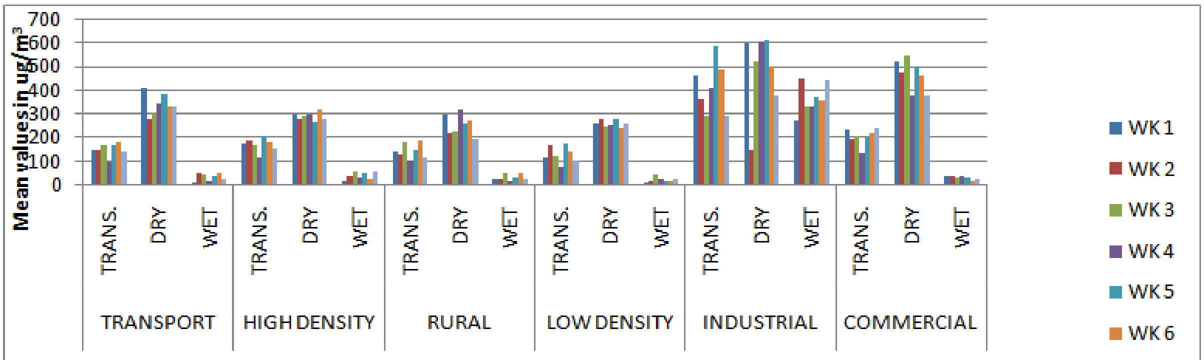

Fig. 1: Mean weekly variations in the concentration of PM_{10} in various landuse areas of Port Harcourt

Table 2: Summary of ANOVA of PM_{10} concentration amongst the various land use during the wet, transition and dry season.

POLLUTANT	SEASON	F. cal	F. crit	Level of significance
PM_{10}	Wet	22. 29	2. 25	significant
	Transition	2. 92	2. 25	Significant
	Dry	4. 50	2. 25	Significant

Significant at 95% confidence level.

The ANOVA in table 1 above decomposes the variance of PM_{10} among the various landuse areas and season into two components: a between-group component and a within-group component. Since the F-calculate value of 22.29, 2.92, and 4.50 repressing the wet, transition and dry season respectively, is greater than the F-crit. value of 2.25, we therefore conclude that "there is a statistically significant spatial weekly variation in the concentration of PM_{10} at the various landuse areas of the city at the 95% confidence level in all the seasons.

6. Implications for Respiratory Health Hazard Management

The implication of the high concentration of PM_{10} at the industrial & commercial areas is that the people who work, live and do business in the areas will be exposed to serious health hazards and risk such as heart & lung diseases, respiratory symptoms which also aid respiratory and cardio vascular diseases. These diseases are expected to be higher among the inhabitants of Woji, Nkpogu, Ogonigba, Rainbow Town, Akpojo, and also Okrika main land and Rumuomasi all high density residential areas sandwiched between the Trans-Amadi and Eleme industrial areas. The commercial areas of Mile 3 market, Wobo Street, Chinda Street, Azikiwe all in Diobu area also exposed to these diseases. Also to be affected are the traders around Creek road market, Bonny street, Niger Street, Bende street all in Port Harcourt town. The percentage seasonal weekly contribution of PM_{10} by the respective landuse indicate that at the industrial areas had the peak value of 65.14%, 29.51% and 16.92% during the wet, dry and transition period respectively. The transport areas accounted for 12.43%, 14.91% and 7.34% during the transition, dry and wet seasons respectively. For the HDR areas, the transition, dry and wet seasons accounted for 14.04%, 12.67% and 7.34% respectively. The rural areas accounted for 11.93%, 11.22% and 6.58% during the transition, dry and wet season respectively. The analysis further revealed that at the commercial areas the seasonal weekly percentage concentration of PM_{10} was 16.92%, 20.22% and 7.08% respectively. Similarly, at the LDR areas, the percentage concentration of PM_{10} increased from 5% during the wet season to 10.67% during the transition period and to 11.33% during the dry season.

The seasonal total atmospheric loading of PM_{10} recorded during the dry, transition and wet season was 16, 148.87μg/m^3; 8,573.12μg/m^3 and 3,436.1μg/m^3 respectively in Port Harcourt.

7. Conclusion

The increase in atmospheric loading of particulate pollutants has its attendant effect on both the environment and the health of residents. It is responsible for respiratory related diseases such as asthma, obstructive pulmonary diseases, and damage lungs tissues. The risk of these diseases is expected to be higher among high density residential areas (such as of Woji, Nkpogu, Nchia, Aleto, Akpojo, Alesa, Ogonigba, Okrika main land, and Elelenwo) sandwiched between the Trans-Amadi and Eleme industrial areas. These areas are located down-wind of the city. The general atmospheric concentration of particulates confirms that Port Harcourt (South Eastern part) is rather uncomfortable during the dry season. The study therefore recommends that adequate space management and planning is a sure way for averting particulate pollutants related disasters in the city. Therefore, the particulates in the city of Port Harcourt needed to be monitored continuously as the levels obtained increase tremendously because of the increasing rate of urbanization and industrialization.

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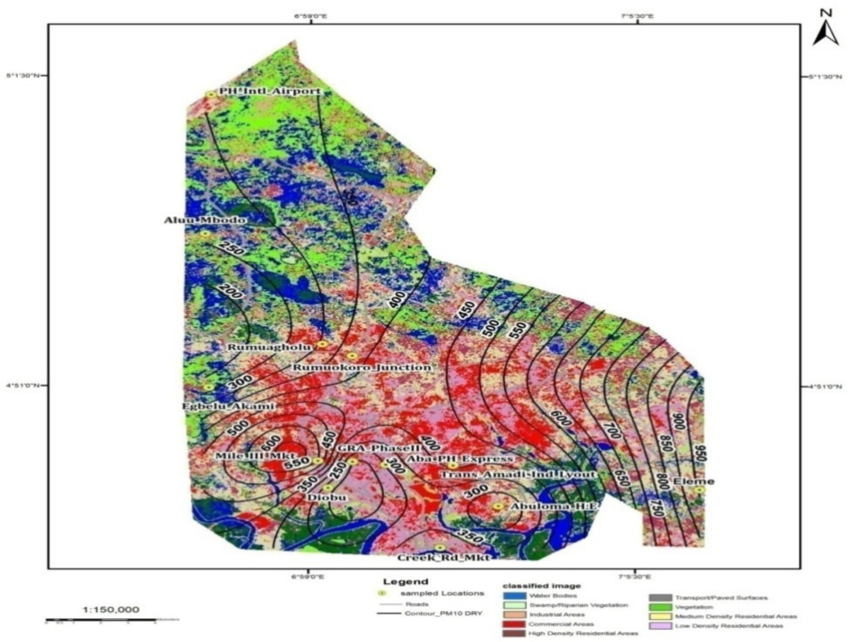

Fig. 2: Particulate matter (10 micron) concentration (in μg/m^3) during dry season(December, 2010 – Jan, 2011).

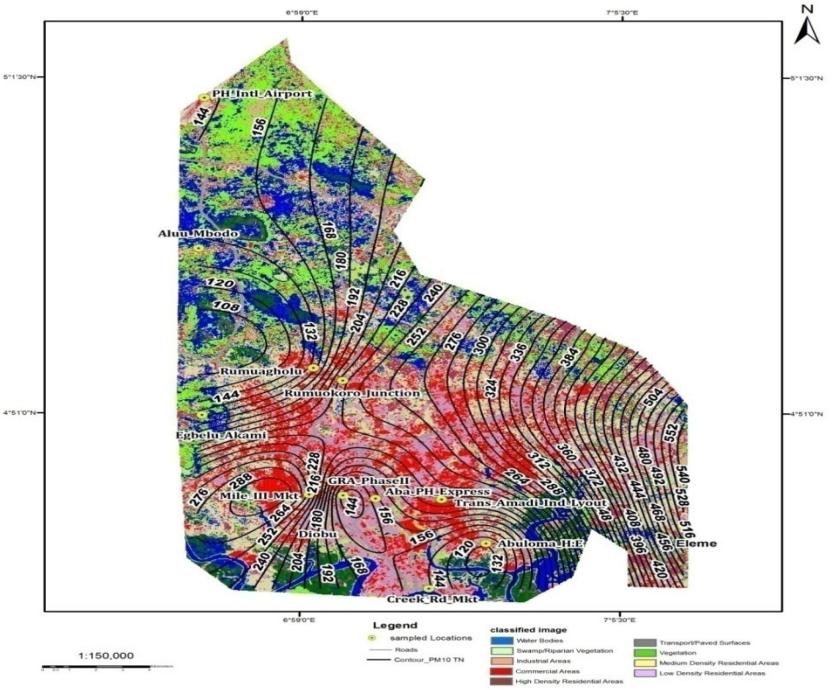

Fig. 3: Particulate matter (10 micron) concentration (in µg/m^3) during transition period (October- November, 2010).

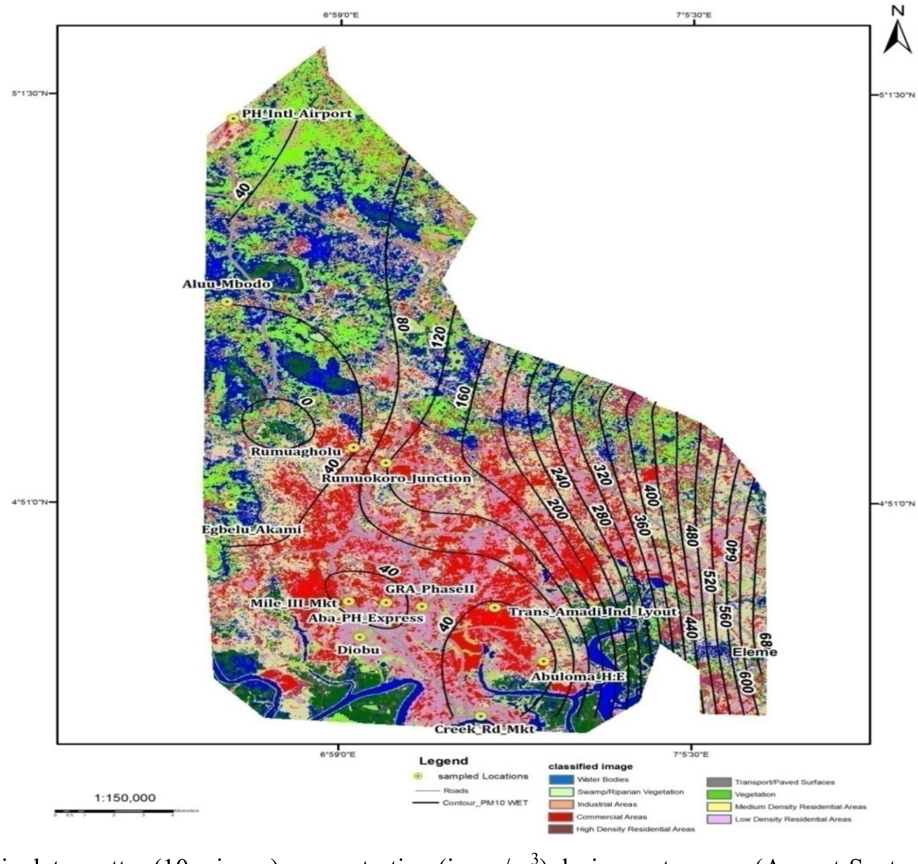

Fig. 4: Particulate matter (10 micron) concentration (in µg/m^3) during wet season (August-September, 2010).