International Journal of Environment and Pollution Research

Vol.5, No.1, pp.52-69, March 2017

Published by European Centre for Research Training and Development UK (www.eajournals.org)

ATMOSPHERIC AEROSOL LOADING OVER THE URBAN CANOPY OF PORT HARCOURT CITY AND ITS IMPLICATIONS FOR THE INCIDENCE OF OBSTRUCTIVE PULMONARY DISEASES

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ABSTRACT: *In view of the deaths arising from obstructive pulmonary diseases, this study examined the concentration of aerosols (Total Suspended Particulates-TSP) as influenced by both landuse and meteorological parameters of wind speed, relative humidity, ambient temperature and rainfall in Port Harcourt city. Air quality and meteorological data were measured at twelve stations: two each from the industrial, high and low density residential, commercial, transportation and surrounding rural areas. Data were collected for seven weeks during wet, transition and dry seasons. Analysis of data was done using ANOVA and stepwise multiple regression techniques. Findings indicated that TSP concentration was highest in the industrial (71.9%), transportation (17.3%), Low Density Residential (LDR) (12.31%); rural (12.9%), and commercial (24%) landuse areas during the dry season. The high Density Residential (HDR) (13.98%) contributed the highest concentration of TSP during the transition period. At the high density residential areas, only air temperature (r= -0.288) during the wet season correlated inversely to the concentration of TSP; other meteorological parameters and their correlation values are rainfall (r=0.133), wind speed (r=0.409) and relative humidity (r=0.095) which correlated directly to TSP concentration. The coefficient of determination values showed that the meteorological variables, jointly accounted for 19.90% and 11.50% of the variation in the concentration of TSP during the wet and dry seasons respectively. Residents who are sensitive to the effects of TSP especially those with chronic obstructive pulmonary or cardiovascular disease must not be allowed to inhabit and spend longer hours in Woji, Nkpogu, Nchia, Aleto, Akpojo, Alesa, Ogonigba, Okrika main land, and Elelenwo communities which are sandwiched between the Trans-Amadi and Eleme industrial areas that are located down-wind of the city. Specific air pollution and environmental standards ought to be more stringent targeting sources like factories, incineration and vehicle emissions.*

KEYWORDS: *TSPs, Land use, Urban Canopy, Respiration Infections, Port Harcourt.*

INTRODUCTION

Traffic, landfill and industrial emissions constitutes the major sources of aerosol (ultrafine particles <10 µm in aerodynamic diameter) pollution in urban centres constituting a major environmental concern due to a lack of effective control measures (Johansson et al., 2007; Morawska et al., 2008; Pey et al., 2009; Harrison et al., 2011; Zagha and Nwaogoezie, 2015). The industrial coastal city of Port Harcourt has the potentials to generate aerosols from these sources. This problem which manifested as black soot in late 2016 and early 2017 is becoming acute as the city continuous to expand into the rural fringes increasing the space of economic activities. Moreso, home appliances, floors and nostril of inhabitants showed the presence of black ultra-fine substances thus concerted efforts are required to solve this problem. Aerosols have the potential to comprise toxic pollutants, such as transition metals, polycyclic aromatic hydrocarbons (PAHs), and other particle-bound organic compounds, which may be responsible for initiating local lung damage, when the particles deposit on the epithelial surfaces (Lighty et al., 2000). Bio-distribution studies suggest translocations of aerosols from the respiratory system to other organs including liver, heart and the central nervous system, in which they can cause adverse health effects (Oberdörster et al., 2005; Kleinman et al., 2008; Kreyling et al., 2013). In the case of atmospheric properties, aerosol cause visibility reduction which may lead to safety hazards, fog formation and precipitation, solar radiation reduction and alteration in temperatures and wind distribution (Jacobson, 2001; Rosenfeld, 2002; Chow et al.,2002; Watson 2002a, b; Cao et al; 2004). Vegetation are not also exempted from the impact of mostly ultra-fine particulates; it causes destruction of the chlorophyll and the destruction of photosynthetic activity which untimely leads to death of plant (Qi, et al.2000). in Port Harcourt, different landuse types, seasons and meteorological conditions are associated with different pollutant generation, concentration and dispersion respectively (Weli, 2014a, Weli and Adegoke, 2016).

With modern activities for development, contamination of the atmosphere by smoke, dusts and other suspended substances collectively referred to as aerosols constantly occur in Port Harcourt city, making the air inhabitants breathe in, a source of hazard to their lives (Weli, 2014b). The United Nations estimated that over six hundred (600) million people in urban areas worldwide were exposed to dangerous levels of atmospheric pollutants (Cacciola et al., 2002). The city of Port Harcourt alone houses over 2 million people, and it is expected that more than half of this population will be at risk of exposure to aerosol pollutants.

In Nigeria and especially in the city of Port Harcourt, much attention has been given to industrial, landfill and traffic gaseous emissions, with little reference to aerosol pollutants (especially ultra-fine particulates >10 µm) from a combination of landuse typology (for example; Ede, 1990; Weli and Koba, 2014; Weli and Adekunle, 2014; Weli, 2014a, b; Zagha and Nwaogozie, 2015, Weli and Adegoke, 2016). From the available literature, it is obvious that there is lack of empirical data on aerosol concentrations from different landuse and their interactions with the meteorological conditions in Port Harcourt metropolis especially their implications for the incidence of cardiovascular diseases. This study therefore attempts to address this gap by quantifying the seasonal and spatial atmospheric aerosol ($PM_{2.5}$, PM_7, PM_{10}) loading over the urban canopy of Port Harcourt metropolis, Nigeria.

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 30^1 E and 5^0 45^1 - 40^0 15^1 N. 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 city are primarily a result of the interplay between two major pressure

ISSN 2056-7537(print), ISSN 2056-7545(online)

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 the region 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 air mass 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).

METHODOLOGY

The collection of TSP Concentration data.

TSP and meteorological data were measured at twelve locations: two each from the industrial, high and low density residential areas, commercial, transport and rural areas (30km away from the city). The collection of air quality and meteorological data for this study covered the period 2nd August to 18th September, 2010 reflecting the wet season; October 4th to November 20th, 2010 for the transition period and January 3rd to February 19th 2011 reflecting the dry season period. This covered about 126 days (42 days each of each three seasons). The choice of these seasons was based on rainfall distribution of Port Harcourt. 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. This sampling framework was adopted to capture the potential fluctuations in TSP concentrations in all the stations for all the seasons. A Met One Instrument, Inc. Aerosol Mass Monitor Mode GT-321 was used to measure Total Suspended Particulates (TSP). This Ambient Particulate was collected and recorded as “real-time” data information on airborne particulate concentration in addition to providing continuous particle monitoring. A laser optical sensor for detecting and measuring particulate concentrations up to 1 milligram per cubic meter was included. A waterproof enclosure containing a laser sensor, flow system and digital recorder was included. Other features include an 8 x 40-character LCD, password protection and automatic alarms that alert one to hazardous conditions. This portable mass monitor is ideal for filter testing, work place monitoring, emissions sampling and air quality surveys. The monitor uses light scatter to measure individual particles instead of clouds like other monitors. In order to select the sampling sites for TSP monitoring, a land use map of the study area with the scale 1: 1,000 was converted into a gridded map of 500 m x 500 m. All the cells of the gridded map were coded by their respective land use type and used to obtain two monitoring stations representing a specific landuse for all twelve stations. The spatial variations in TSP concentration in this study were evaluated by analyzing the actively sampled TSP data obtained with the aeroset from the different land use areas chosen in this

ISSN 2056-7537(print), ISSN 2056-7545(online)

study on daily basis. The analysis was based on the data collected throughout the seasons considered in this study. The objective was to ascertain and/or identify the mean weekly spatial variations in the concentration of TSP at the respective land use areas. The seasonal variation in TSP concentration was done amongst the landuse types interacting with the influence of the meteorology of the urban canopy to determine the difference in the concentration of TSP at different seasons of the year. Table 1 shows the geographical coordinates of the areas which constitute the major land use areas used for the study. The data was analysed using two- way Analysis of Variance and Stepwise Multiple Regression (SMR) technique with the aid of SPSS statistical software. For all the land use types, effort was made to identify the general wind direction. This was 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: Geographical coordinates of sampled stations.

Landuse	Stations	Latitudes (^{0}N)	Longitudes (^{0}E)
Industrial	Eleme	$4^0\ 47^1$	$7^0\ 6^1$
	Trans-Amadi	$4^0\ 48^1$	$7^0\ 1^1$
High density residential	Diobu	$4^0\ 47^1$	$6^0\ 59^1$
	Rumuagholu	$4^0\ 52^1$	$6^0\ 59^1$
Low density residential	GRA	$4^0\ 48^1$	$6^0\ 59^1$
	Abuloma housing estate	$4^0\ 46^1$	$7^0\ 2^1$
Commercial	Mile III Market	$4^0\ 48^1$	$6^0\ 59^1$
	Creek road market	$4^0\ 45^1$	$7^0\ 1^1$
Transport	PH-Aba exprees way	$4^0\ 48^1$	$7^0\ 0^1$
	Ikwerre road	$4^0\ 52^1$	$6^0\ 59^1$
	PH Int'l Airport	$5^0\ 0^1$	$6^0\ 57^1$
Rural	Aluu	$4^0\ 56^1$	$6^0\ 56^1$
	Egbelu-akami	$4^0\ 50^1$	$6^0\ 57^1$

The relationship between weather parameters and TSP concentration at the sampled points were examined using the Multiple Linear Regression (MLR) analysis. The TSP concentration was the dependent variable and the other atmospheric parameters were the independent variables. This enabled us to identify the degree and nature of the relationship between the climatic parameters and TSP concentrations in the city. The multiple regression technique is of the form;

$$Y = a + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 \ldots + \beta iji + e \quad (1)$$

Where,

Y = Pollutant concentration,

a = Constant term

$\beta_1\ \beta_2\ \beta_3 \ldots \beta_J$ = Regression coefficients

$X_1\ X_2\ X_3 \ldots X_J$ = Independent variables (air temperature, wind speed and relative humidity)

ISSN 2056-7537(print), ISSN 2056-7545(online)

The Application of GIS in Generating Land use - TSP Concentration Maps

Geo Spatial Data Processing and Analysis

Landsat Enhanced Thematic Mapper Plus (ETM+) image of 2007 covering the four LGAs (i.e. Eleme, Obi/Akpor, Port Harcourt and Ikwerre) was obtained for this study. The Landsat ETM+ satellite data was processed using ERDAS IMAGINE 9.2 image processing software. The image was imported into ERDAS using ERDAS native file format GEOTIFF. Since the images were in single bands, they were stacked together using ERDAS layer stack module to form a floating scene and to group the bands together. The 2007 image was co-registered with other images and later geo-linked to allow for the subset of the image to the study area. This was followed by performing further Geometric corrections of the 2007 image to remove few scattered clouds in the image. The image was projected to the Universal Traverse Mercator (UTM) coordinates zone 32. The spheroid and datum was also referenced to WSG84. Enhancement of the images using histogram equalization techniques was later performed on the image and subset to an area to cover the four LGA. The image was later displayed as false-color composites with band combination of red as band 4, green as band 3, and blue as band 2. All the images were later categorized using supervised classification technique to identify land cover features within the study area. The supervised classification was done by defining the number of classes to be 10 depending on the number of possible classes that can be readily identified by the software. Names were later assigned to the classes based on the patterns that could be identified. The classified map was later imported into ArcGIS 9.2 software for preparation and production.

Contour Creation and Data Preparation

The following steps were taken to prepare the data.

1. The XY data i.e. the sample points obtained from the field was prepared in Excel Spread Sheet and saved in a format recognized by ArcGIS
2. The Points were plotted in ArcGIS by the use of the ADD XY data module found in the Tool Menu of ArcGIS 9.2 software.
3. An Attribute database was created for the sample points during which all the values obtained from the field were keyed into their respective sampled stations field or Row and Columns

Data Analysis

The Spatial Analyst Tool in the ArcToolBox was used to analyze the data obtained from the field after its preparation so as to meet the necessary conditions that permit its analysis in ArcGIS. Two tools were used, one is the SPLINE tool for data Interpolation found in the Spatial Analyst and the second is the CONTOUR tool present in the Surface analysis Box for carrying out surface analysis such as Contours, Aspect, and Slope etc. The contour maps were created from the SPLINE data generated from the sample points and the TSP concentration for the different seasons (wet, transition and dry seasons). The Produced contour maps were later superimposed on the landuse map generated earlier. Labeling of the contour values and the sample stations were done and the map was taken to layout view for preparation and production. The produced maps were finally exported and saved in jpegs for easy accessibility to Word document.

ISSN 2056-7537(print), ISSN 2056-7545(online)

RESULTS AND DISCUSSION OF FINDINGS

The spatial variations in the concentration of TSP.

In this section, the mean daily variations in the concentration of aerosols among the various landuse areas of Port Harcourt were investigated. Figure 4.2 reveal that on the first week of measurement, aerosol had the highest concentration value of 684.41µg/m^3 at the industrial areas during the transition period. This was followed by the transport land use areas with a value of 401.83µg/m^3; commercial 344.41µg/m^3, high density residential 222.66µg/m^3, Rural, 196µg/m^3 and low density residential areas had an aerosol value of 176.5µg/m^3, the lowest recorded in the first week. During the dry season, transport, HDR, rural, LDR, industrial and commercial landuse areas had aerosol values of 53.7.8µg/m^3, 366.2µg/m^3, 430.8µg/m^3, 357.1µg/m^3, 835µg/m^3 and 738.4µg/m^3 respectively. For the wet season the values of aerosol were 10.16µg/m^3, 22µg/m^3, 27.33µg/m^3, 13.16µg/m^3, 278µg/m^3, and 42µg/m^3 respectively for the transport, HDR, rural, LDR, industrial and commercial landuse areas.

The second week of sampling at the various land use areas of Port Harcourt showed that during the transition period aerosol had the highest concentration value of 482.08µg/m^3 at the industrial area. This is followed by the commercial areas with a value of 316.66µg/m^3. The value of aerosol was observed as 191.41µg/m^3 at the transport land use areas, for high density residential areas, it was 286.5µg/m^3; 160.66µg/m^3 for rural and 206.08µg/m^3 for the low density residential areas.

For the dry season, the values of aerosol were 429.3µg/m^3, 35µg/m^3, 326.6µg/m^3, 318.4µg/m^3, 243.9µg/m^3, and 671.8µg/m^3 respectively for the transport, HDR, rural LDR, industrial and commercial landuse areas. During the wet season the transport, HDR, rural, LDR, industrial and commercial landuse areas had aerosol values of 71.25µg/m^3, 52.6µg/m^3, 30.6µg/m^3, 29.41µg/m^3, 562.3µg/m^3, and 43.7µg/m^3 respectively. With the industrial and transport landuse types leading in the concentration of aerosol during the wet season; and the commercial and transport landuse types leading in aerosol concentration during the dry season.

The value of aerosol for the third week showed that during the transition period the industrial land use areas continue to increase with a value of 385.75µg/m^3, followed by the commercial area with a value of 268.166µg/m^3. The values were 214.166µg/m^3 at the transport land use; 223.16µg/m^3 at high density residential area; 164.54µg/m^3 at rural areas and 164.25µg/m^3 at low density residential areas of the city.

ISSN 2056-7537(print), ISSN 2056-7545(online)

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Published by European Centre for Research Training and Development UK (www.eajournals.org)

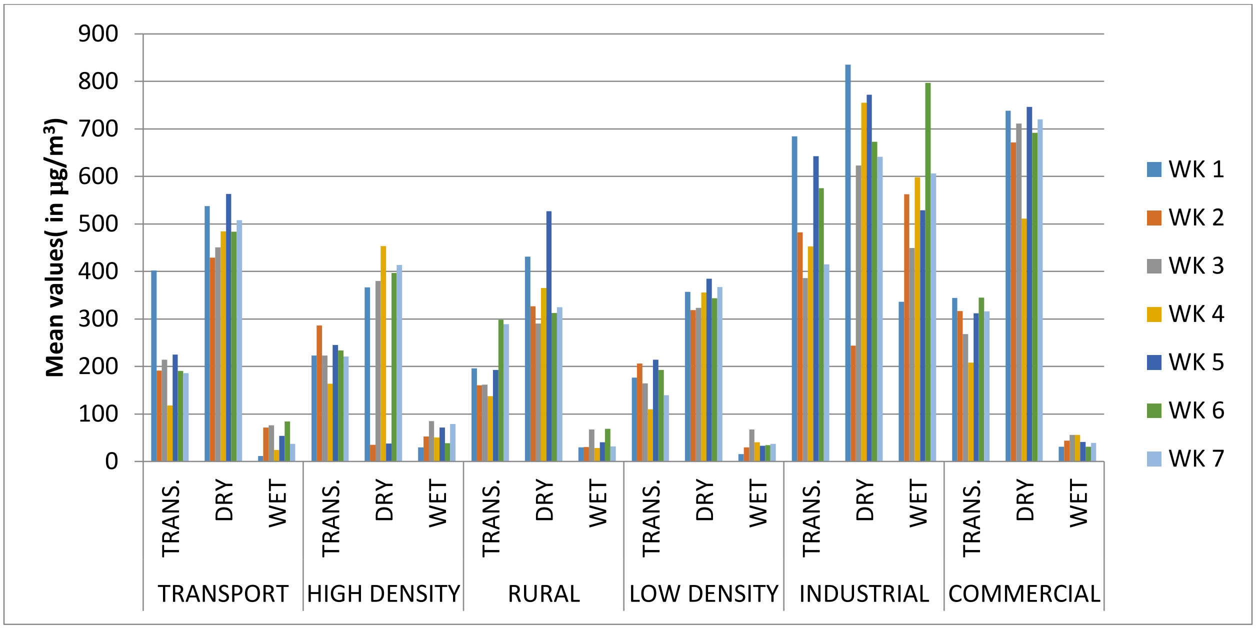

Fig 1: Mean weekly variations in the concentration of aerosol in various landuse areas of Port Harcourt

For the dry season the transport, HDR, rural LDR, industrial and commercial landuse areas had aerosol values of 450.8µg/m^3, 379.9µg/m^3, 290.6µg/m^3, 323.6µg/m^3, 623µg/m^3, and 711.2µg/m^3 respectively, while during the wet season the values were 76.41µg/m^3, 84.6µg/m^3, 67.3µg/m^3, 67.3µg/m^3, 449.2µg/m^3, and 55.7µg/m^3 for the transport, HDR, rural, LDR, industrial and commercial landuse areas respectively. On the fourth week the highest concentration of aerosol was similarly observed during the transition period at the industrial areas with a mean value of 452.58µg/m^3. This is followed by the commercial areas with value of 207.91µg/m^3; high density residential, 164µg/m^3, rural areas, 137.37µg/m^3; transport, 117.66µg/m^3 and finally the lowest value measured at the low density residential area with a value of 109.75µg/m^3. For the dry season period the values were 484.01µg/m^3, 453.1µg/m^3, 365.3µg/m^3, 355.5µg/m^3, 755.4µg/m^3, and 511.41µg/m^3 for the transport, HDR, rural, LDR, industrial and commercial landuse areas respectively, while during the wet season the transport, HDR, rural, LDR, industrial and commercial landuse areas had concentration values of 24.5µg/m^3, 50.5µg/m^3, 28.08µg/m^3, 40.58µg/m^3, 598.4µg/m^3, and 55.8µg/m^3 respectively. The concentration of TSP on the fifth week during the transition period showed that the industrial area continues to increase the atmospheric loading of aerosol with a value of 642.50µg/m^3. This is followed by the commercial areas with a value of 312µg/m^3; high density residential, 244.91µg/m^3, transport, 224.75µg/m^3, low density residential, 214.41µg/m^3 and rural with a value of 192.58µg/m^3. During the dry season, the values of aerosol were 562.8µg/m^3, 376µg/m^3, 56.8µg/m^3, 384.5µg/m^3, 772.2µg/m^3, and 746.4µg/m^3 for the transport, HDR, rural, LDR, industrial and commercial landuse areas respectively, while during the wet season the transport, HDR, rural, LDR, industrial and commercial landuse areas had aerosol values of 52.6µg/m^3, 71.1µg/m^3, 40.5µg/m^3, 33µg/m^3, 528.7µg/m^3 and 40.8µg/m^3 respectively.

ISSN 2056-7537(print), ISSN 2056-7545(online)

The concentration of TSP on the sixth week among the various land use areas of Port Harcourt investigated during the transition period revealed that the industrial area had the highest value of 575μg/m^3; followed by the rural area with a value of 298.10μg/m^3. Transport had 190.78μg/m^3. High density residential, 233.41μg/m^{3}and low density residential with a value of 192.58μg/m^3. The dry season variation in the concentration of TSP showed that the transport, HDR, rural, LDR, industrial and commercial landuse areas had concentration values of 483.5μg/m^3, 396.4 μg/m^3, 312.5 μg/m^3, 343.8 μg/m^3, 672.8 μg/m^3, and 691.8μg/m^3 respectively with industrial and commercial areas leading in concentration. During the wet season the values of TSP were 84.5 μg/m^3, 38.4 μg/m^3, 68.7 μg/m^3, 34.5 μg/m^3, 796.9μg/m^3 and 31.2 μg/m^3 at the transport, HDR, rural, LDR, industrial and commercial landuse areas respectively.

The concentration of TSP on the seventh week during the transition period showed a marked variation with the industrial area contributing more into the atmosphere of the city, with a value of 537.25 μg/m^3, this is followed by the commercial area with a value of 304.42 μg/m^3; Transport, 246.98 μg/m^3; High density residential 231.94 μg/m^3; Rural; 218.65 μg/m^3 and Low density residential with a value of 172.82 μg/m^3. The commercial areas contributed more TSP during the dry season with a value of 720μg/m^3. At the transport, HDR, rural, LDR and industrial areas, the values were 508.1μg/m^3, 413.5μg/m^3, 324.5μg/m^3, 367.4μg/m^3 and 641.1μg/m^3 respectively. The study showed that 31.6% and 71.9% of the concentration of aerosol was contributed by the industrial area during the transition, dry and wet season respectively. The transport landuse areas accounted for 13.2%, 17.3%, and 6.6% during the transition, dry and wet seasons respectively. From the High density residential areas, the seasonal percentage concentration of TSP was, 13.8%, 10.4% and 7.5% during the transition, dry and wet seasons respectively. The rural areas contributed 12.4%, 12.9% and 5.4% of TSP during the transition, dry and wet season respectively. In the case of LDR, the seasonal percentage contributed of aerosol was 10.45%, 12.31% and 4.7% during the transition, dry and wet season respectively. The commercial area accounted for 18.3%, 24.0% and 5.5% during the transition, dry and wet season respectively.

Generally, the seasonal concentration of TSP revealed that the dry season had the highest contribution of 19,899.42 μg/m^3, followed by the transition season with a value of 11,504.98 μg/m^3 with the industrial, commercial and the HDR areas accounting for over 60%. For the wet season, the value was 5,392.39 μg/m^3. However, to examine the spatial variation in the concentration of TSP across the various landuse areas, the mean daily values where used for the analysis of variance test as shown in table 2.

Table 2: Summary of ANOVA of aerosol concentration amongst the various landuse during the wet, transition and dry season.

POLLUTANT	SEASON	F.cal.	F.crit.	Level of significance
Aerosol	Wet	112.40	2.25	Significant
	Transition	24.83	2.25	Significant
	Dry	8.67	2.25	Significant

Significant at 95% level, F-Snedecor's value

The ANOVA in table 2 decomposes the variance of TSP 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 112.40, 24.8 and 8.6 representing 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 TSP at the various landuse areas of the city at the 95% confidence level in all the seasons. The concentration of TSP across the Transport, Industrial and Commercial areas implies that lung diseases will be prevalent in this land use areas. Therefore, the elderly and the children who are the major sensitive subgroup of the population sensitive to the effects of TSP especially those individual with chronic obstructive pulmonary or cardiovascular disease will be impacted severely and must not be allowed to inhabit these areas for a long time.

Seasonal Variation in The Concentration of Total Suspended Particulate Matter at the Various Land Use Areas.

Fig. 2 shows the seasonal variation in the concentration of Total Suspended Particulate matter (TSP) among the various land use areas of Port Harcourt. The figure revealed that the concentration of TSP was all high between the transport and industrial, the highest peak was observed during the dry season at the industrial areas with a value of 1105.67µg/m^3. This is followed by the commercial area with a value of 684.45µg/m^3 during the dry season. The concentration of TSP was also high at the transport land use areas with a value of 493.84µg/m^3, also during the dry season. The figure 5.2 below is a bar graph of the seasonal and spatial variation of TSP concentrations in the various landuse areas of Port Harcourt.

ISSN 2056-7537(print), ISSN 2056-7545(online)

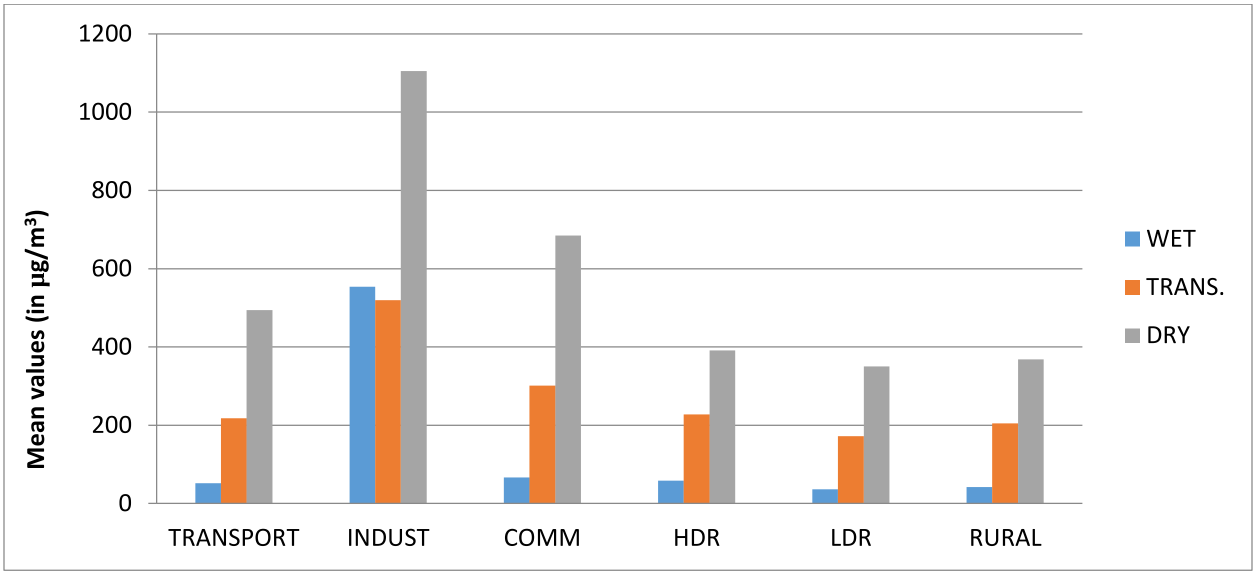

Fig. 2: Mean seasonal variations in the concentration of TSP at various landuse areas of Port Harcourt.

For the High density and low density residential areas, the values of TSP were measured to be 391µg/m^3, 350.05µg/m^3 during the dry season respectively. The value of TSP was however high in the rural area when compared with the low density residential area with a value of 368.23µg/m^3 during the dry season.

Similarly, during the transition period, the highest concentration of TSP was measured at the industrial area with a value of 519.65µg/m^3. At the commercial areas, TSP was recorded as 300.98µg/m^3 and 218.08µg/m^3 at the transport areas. It is also important to note that the concentration of TSP during the transition period at the high density residential area was measured to be 227.98µg/m^3 higher than the transport areas (see figures 5.6, 5.7, and 5.8) During the wet season, the industrial areas had a peak TSP value of 554.05µg/m^3, transport, 51.48µg/m^3, commercial 66.77µg/m^3; High density residential, 58.22µg/m^3; Low density 36.49µg/m^3 and rural area with a TSP mean value of 4233.00 µg/m^3 during the wet season.

The result of the two-way ANOVA on the concentration of TSP in the study area revealed that since the F-calculated values of the rows representing the different landuse areas (5.56) and the columns representing the different seasons investigated (16.90) are above the F-critical values of 2.82 and 4.84 respectively, we can conclude therefore that there was a significant seasonal and spatial difference in the occurrence and concentration of TSP in Port Harcourt metropolis. The concentration of TSP across the transport, industrial and commercial areas implies that lung diseases will be prevalent in this land use areas. Therefore, the elderly and the children who are the major sensitive subgroup of the population sensitive to the effects of TSP especially those individual with chronic obstructive pulmonary or cardiovascular disease or influencing must not reside in these areas to avoid the aggravation of these diseases. It is expected that these diseases will be highest during the dry season at the transport landuse areas and for all the seasons at the industrial area. But at the commercial areas, the dry season periods will pose serious health risks to the vulnerable part of the population.

ISSN 2056-7537(print), ISSN 2056-7545(online)

Table 3: ANOVA of TSP at different landuse areas and seasons.

Source of variation	*SS*	*df*	*MS*	*F*	*P-value*	*F.crit*
Rows (landuse)	1638745	11	148976.8	5.56393	0.004163	2.81793
Columns (seasons)	452620.5	1	452620.5	16.9043	0.001725	4.844336
Error	294530.1	11	26775.47			
Total	2385896	23				

Significant at 95% level.

The section below presents GIS based map of the spatial and seasonal TSP concentration in the city of Port Harcourt.

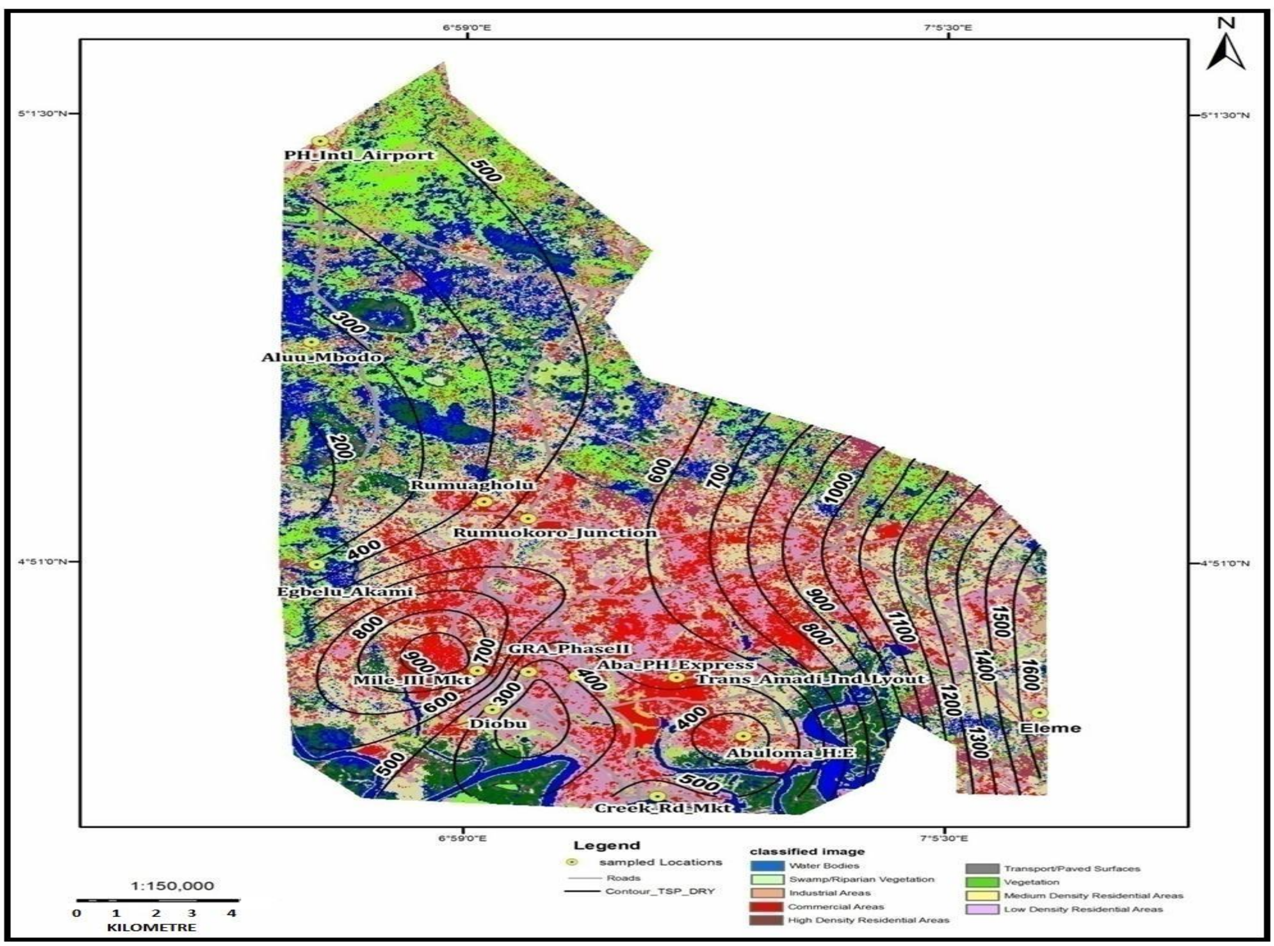

Fig.3: TSP concentration (in µg/m^3) during dry season

ISSN 2056-7537(print), ISSN 2056-7545(online)

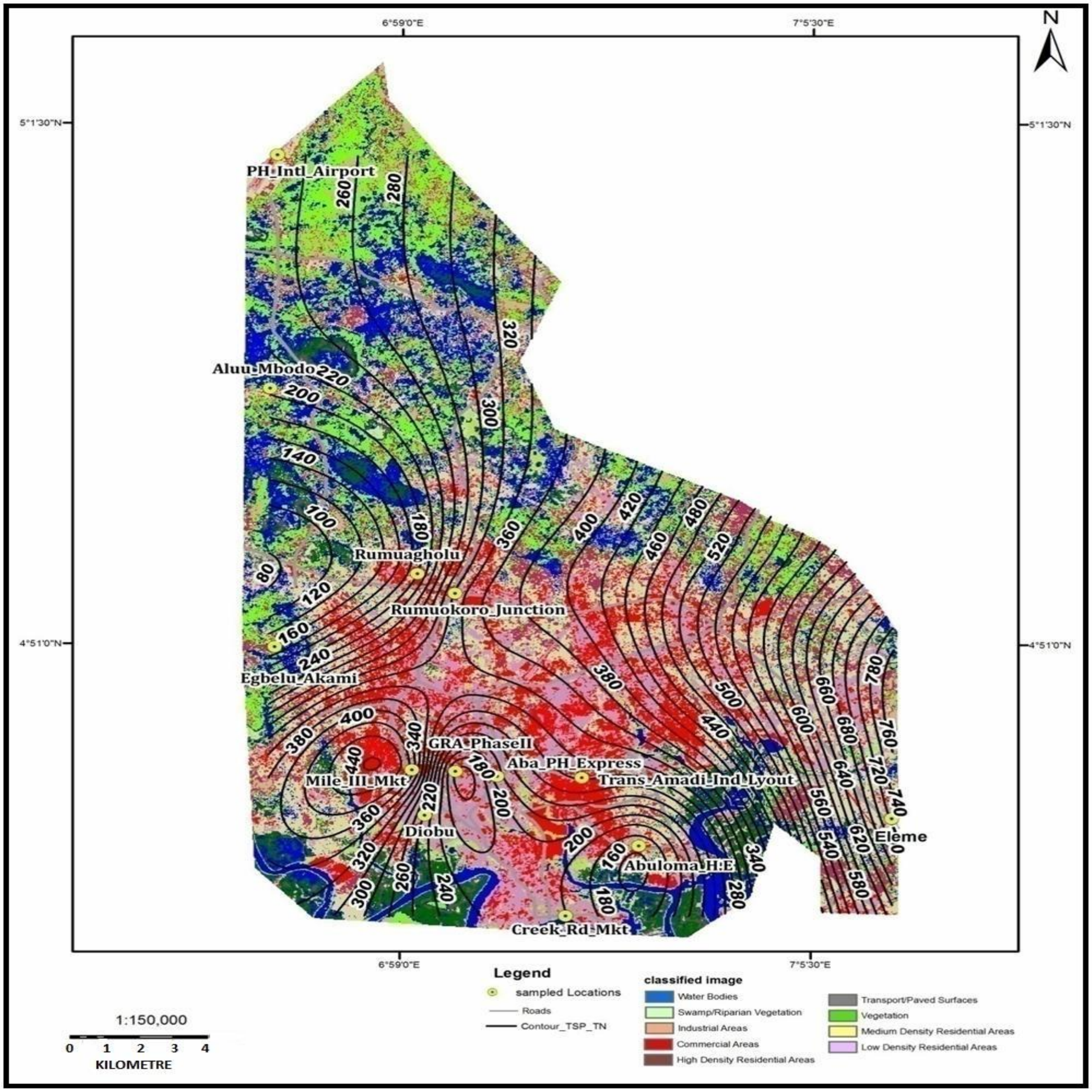

Fig. 4: TSP concentration (in µg/m^3) during transition period

ISSN 2056-7537(print), ISSN 2056-7545(online)

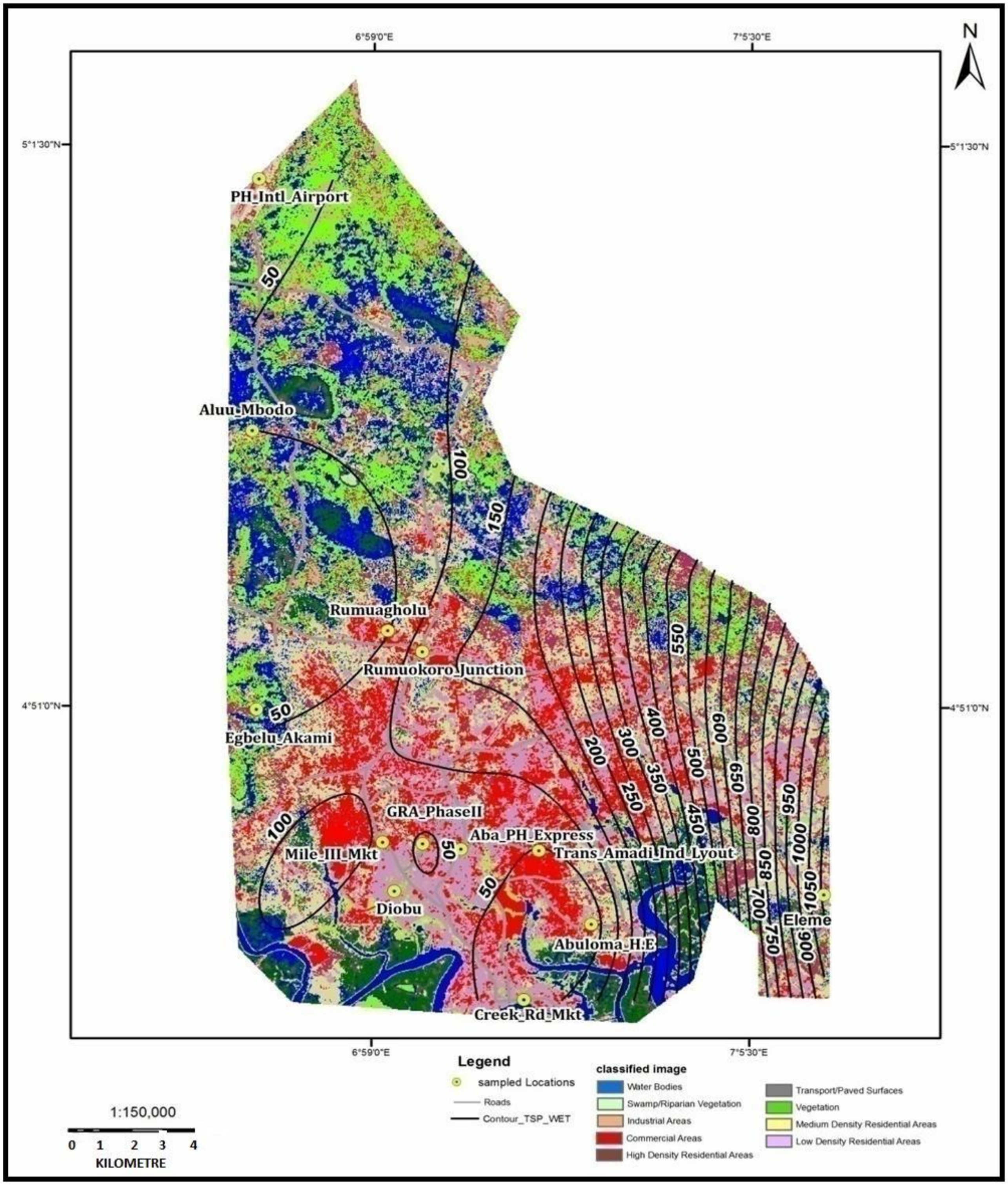

Fig. 5.: TSP concentration (in µg/m^3) during wet season (August – September, 2010).

ISSN 2056-7537(print), ISSN 2056-7545(online)

The relationship between TSP concentration and meteorological parameters in various landuse areas.

Result showed that models were produced for transport land use, commercial, high density residential and low density residential areas during the wet season respectively. The correlation matrix between the meteorological parameters and TSP at the transport land use during the wet season showed that wind speed (-0.046) correlated inversely to the concentration of TSP while rainfall, (0.093) air temperature (0.134) and relative humidity correlated and relative humidity values were also low. Because of this, they aided the concentration of TSP. table 6.3) show that relative humidity was the only meteorological variable that was significant at 99% with F-calculated value of 7.503 which is greater than the F-critical value of 7.31. We therefore accept the alternate hypothesis that there is a significant impact of relative humidity on the concentration of total suspended particulate (TSP) during the wet season at the transport land use areas. The coefficient of determination revealed that jointly, the meteorological variable accounted for 15.8% of the variation in the concentration of TSP. At the commercial areas during the wet season, the correlation values of rainfall (-0.25), air temperature (-0.11), and relative humidity (-0.21) correlated inversely to the concentration of TSP. This is because rainfall, air temperature and relative humidity values were high at the commercial areas and therefore encouraged the dispersion of TSP. But only wind speed with a correlation value of (0.128) relates directly to TSP concentration. This is because the wind was calm and therefore aided the concentration of TSP at the commercial areas during the wet season. At the 95% significant level, relative humidity was significant in determining the concentration of TSP during the wet season. Given an F-calculated value of 5.24 greater than the F-critical value of 4.08, we therefore reject the null hypothesis and accept the alternate hypothesis that there is a significant impact of wind speed on TSP concentration during the wet season. The coefficient of determination revealed that jointly, the meteorological variables accounted for 11.60% of the variations in the concentration of TSP at the commercial areas during the wet season. At the high density, residential areas, during the wet season, only air temperature with a negative correlation value of -0.288 correlated inversely to the concentration of TSP; other meteorological parameters and their correlation values are rainfall (0.133), wind speed (0.409) and relative humidity (0.095) which correlated directly to TSP concentration. This relationship is established because air temperature value was high enough to cause the dispersion of TSP while the values of rainfall, wind speed and relative humidity were very low and therefore encouraged the concentration of TSP during the wets season at the high density residential areas of Port Harcourt.

At 99% significant level, wind speed was significant in determining the concentration of TSP during the wet season at the commercial areas of the city. Jointly, the meteorological variables accounted for 20.5% of the variation in the concentration of TSP as revealed by the coefficient of determination with an r^2 value of 0.20 at the commercial areas during the wet season. The r^2 statistics for TSP concentration during the wet, transition and dry season revealed that regression models were produced for the low density residential areas during the wet and dry seasons (table 6.3). At the low density, residential areas rainfall correlated inversely to TSP concentration during the wet season. But other meteorological parameters with correlation values such as; air temperature (0.04), wind speed (0.41) and relative humidity (0.27) correlated directly to TSP concentration. But during the dry season, both rainfall and wind speed correlation inversely to the concentration of TSP while air temperature and relative humidity with the correlation values of 0.17 and 0.35 respectively, correlated directly to TSP concentration.

ISSN 2056-7537(print), ISSN 2056-7545(online)

The analysis further revealed that wind speed was significant during the wet season at 99% and relative humidity was also significant but at 95% significant level at the low density residential areas. Also, given their F-calculated and F-critical values, we therefore conclude that “there are significant impacts of wind speed and relative humidity levels on TSP concentration at the low density residential areas during the wet and dry seasons respectively. The coefficient of determination values showed that the meteorological variables, jointly accounted for 19.90% and 11.50% of the variation in the concentration of TSP during the wet and dry seasons respectively.

At rural areas, models were produced for the transition and dry seasons. During the transition period, rainfall (-0.06) and relative humidity (-0.08) had an inverse relationship with TSP concentration, while air temperature and wind speed had a direct relationship with the concentration of TSP at the rural areas. But during the dry season for which regression was also produced, both air temperature (-0.01) and wind speed (-0.01) related inversely with TSP concentration. The analysis in table 6.3 further revealed that rainfall and relative humidity was significant in impacting on TSP concentration at 95% and 99% during the transition and dry seasons respectively. Given their F-calculated values and critical F values, (table 6.3) we therefore concluded that there are significant impacts of rainfall and relative humidity levels on the concentration of TSP during the transition and dry seasons at the rural areas respectively. The coefficient of determination values showed that jointly, the meteorological variables accounted for 10.5% and 16.1% of the variation in the concentration of TSP during the transition and dry seasons respectively.

The predictive models for TSP in all the land use types and seasons for which regression was produced are stated in table 6.4.

Table 6.3: r^2 statistics for TSP concentration during the wet, transition and dry seasons

Landuse	SEASON	R	r^2	F	P-values	Critical F-values	variables in the equation	SSE
Transport	Wet	0.397	0.158	7.503	0.009	7.31	TSP/RHUM**	32.0
	Transition	-	-	-	-		-	-
	Dry	-	-	-	-		-	-
Industrial	Wet	-	-	-	-		-	-
	Transition	-	-	-	-		-	-
	Dry	-	-	-	-	-	-	-
Commercial	Wet	0.340	0.116	5.245	0.027	4.08	TSP/RHUM*	132.48
	Transition	-	-	-	-		-	-

ISSN 2056-7537(print), ISSN 2056-7545(online)

	Dry	-	-	-	-		-	-
High density residential	Wet	0.453	0.205	10.334	0.003	7.31	TSP/WS**	27.15
	Transition	-	-	-	-	-	-	-
	Dry	-	-	-	-	-	-	-
Low density residential	Wet	0.446	0.199	9.908	0.003	7.31	TSP/WS**	18.27
	Transition	-	-	-	-	-	-	-
	Dry	0.339	0.115	5.202	0.028	4.08	TSP/RHUM*	83.97
Rural	Wet	-	-	-	-	-	-	-
	Transition	0.324	0.105	4.702	0.036	4.08	TSP/RFALL *	168.32
	Dry	0.401	0.161	7.654	0.009	7.31	TST/RHUM**	116.42

**Significant at 95% **Significant at 99%, -No Variance and /or Pollutant not detected, RHUM-Relative Humidity, WS-Wind Speed, TEMPT-Temperature, RFALL- Rainfall.*

Table 6.4: Predictive model summary for TSP

MODEL S/N	LANDUSE	PREDICTION MODEL
1	Transport (WET)	$TSP_{Conc.} = -148.409 + 2.593_{(RHUM)} + 32$
2	Commercial (WET)	$TSP_{Conc.} = 543.152 – 7.020_{(RHUM)} + 132.48$
3	High Density Residential (WET)	$TSP_{Conc.} = 30.520 + 43.210_{(WS)} + 27.15$
4	Low Density Residential (wet)	$TSP_{Conc.} = 24.912 + 13.968_{(WS)} + 18.27$
5	Low Density Residential (dry)	$TSP_{Conc.} = 109.811 + 8.540_{(RHUM)} + 83.97$
6	Rural (transition)	$TSP_{Conc.} = 164.768 + 12.841_{(RFALL)} + 198.32$
7	Rural (dry)	$TSP_{Conc.} = -681 + 21.523_{(RHUM)} + 116.42$

IMPLICATIONS TO THE INCIDENCE OF OBSTRUCTIVE PULMONARY DISEASES

Chronic obstructive pulmonary disease (COPD) is a leading cause of world-wide mortality and disability. On average approximately 5-15% of adults in industrialized countries have COPD defined by spirometry. In 1990, COPD was considered to be at the twelfth position world-wide as a cause of combined mortality and disability but is expected to become the fifth cause by the year 2020 (Anto, 2001). In view of the above this study examined the concentration of aerosol and its implications for the

ISSN 2056-7537(print), ISSN 2056-7545(online)

incidence of COPD. The results revealed that Residents who are sensitive to the effects of TSP especially those with chronic obstructive pulmonary or cardiovascular disease must not be allowed to inhabit and spend longer hours in Woji, Nkpogu, Nchia, Aleto, Akpojo, Alesa, Ogonigba, Okrika main land, and Elelenwo communities which are sandwiched between the Trans-Amadi and Eleme industrial areas that are located down-wind of the city. This is because the concentration of aerosols was high in all seasons and similarly, vulnerability to COPD is expected to be very high.

CONCLUSION

The concentration of TSP across the transport, industrial and commercial areas implies that these landuse areas have the potential for lung diseases. Therefore, the elderly and the children who are the major sensitive subgroup of the population to the effects of TSP especially those individual with chronic obstructive pulmonary or cardiovascular disease or influence must not reside in these areas to avoid the aggravation of these diseases. It is expected that these diseases will be highest during the dry season at the transport landuse areas and for all the seasons at the industrial area. But at the commercial areas, the dry season periods will pose serious potential health risks to the vulnerable part of the population. Laws on environment, as they pertain to air quality regulations, are presently very weak in Nigeria and existing environmental standards do not include specific provisions for all possible emission sources. Stakeholders at all level in the country have to articulate initiatives that support quality environmental practices. Specific air pollution and environmental standards ought to be more stringent targeting sources like factories, incineration and vehicle emissions.

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ISSN 2056-7537(print), ISSN 2056-7545(online)