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Full Length Research Paper

Spatial and seasonal analyses of traffic-related pollutant concentrations in Lagos Metropolis, Nigeria

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Leaf samples of *Terminalia catappa L (*Almond) trees dominant in Lagos metropolis, Nigeria were collected from 34 sampling points located within dominant land-uses (commercial, residential, industrial, institutional, acquisition/parks, dumpsites/incinerators and transportation) along traffic corridors and six stations located 250 m away (as control) during the short wet and short dry seasons for two years. Concentration of trace elemental pollutants: (Pb, Cd, Cu, Cr, Al, Zn, As, Hg, Fe, Mn, Mg) were determined by laboratory analyses of leaf samples. Multivariate analysis was used to test for significant geographical and seasonal variations in air pollutants. Total suspended particulate matter varied from 22.36 - 29.07 mg/m^3 against WHO Air Quality Standard (AQS), 0.05 - 0.15 mg/m^3; Sulphur-dioxide and Ozone varied from 1.1 - 1.73 mg/m^3 and 0.01 - 0.18 mg/m^3 respectively as against 0.00125 and 0.0015 mg/m^3 AQS. ANOVA showed spatio-temporal variations in pollutants and significant correlation of traffic density with all metals studied ($P < 0.05$). Lead varied from 1.4 - 3.1 mg/m^3 and 1.7 - 2.6 mg/m^3, Cadmium varied from 1.7 - 3.15 mg/m^3 and 0.011 - 0.1 mg/m^3, Iron varied from 3.06 - 3.6 mg/m^3 and 0.5 - 2.6 mg/m^3, while Arsenic varied from 0.9 - 1.98 mg/m^3 and 0.011 - 0.1 mg/m^3 along traffic corridors and at control points respectively. Step-wise regression analyses further showed that traffic density, air temperature and land-use contributed significantly to air pollution ($P < 0.05$). The micro-climate of Lagos metropolis is characterised by relatively high air temperature, low wind speed and air pollution that varied according to traffic density and land-use. Concentrations of pollutants were higher than the WHO Air Quality standards and were also higher along traffic corridor than further away.

Key words: Lagos metropolis, air pollution, bio-monitoring, traffic density, land-use.

INTRODUCTION

One of the key indicators of the quality of life is a clean environment, which can be further disaggregated in terms of water, noise and air qualities. During the last 200 years, humans began to significantly alter the composition of the atmosphere through pollution. Although air is still made up mostly of oxygen and nitrogen gases, mankind, through its pollution activities, has increased the levels of many trace gases and in some cases, released new gases into the atmosphere (Akanni, 2008). Ambient air pollution in the presence of one or more contaminants in the outdoor atmosphere or the combinations thereof in such quantities and of such duration over and above the natural physical diffusion, deposition, chemical elimination and biological purification functions as may be or may tend to be injurious to human, plant or animal life, or which may unreasonably interfere with the comfortable enjoyment of life or property or the conduct of business (Xie et al., 1998; Zhongan, 2006). Urban canopy pollution resulting from urbanization is one of the microclimatic problems faced in many major urban centres including Lagos metropolis, the air along traffic corridors where majority of residents in the formal and informal sectors (petty traders, street hawkers, vulcanizers, bus drivers and conductors, roadside shop operators, schoolchildren, police officers and traffic wardens) subsist daily to conduct their daily economic activities could hardly be regarded as fresh. The interest in air pollution is related to the fact that air contains oxygen essential for life, what is even more important is that air quality has a direct influence on human health and basic functions such as breathing. All pollutants discharged into the atmosphere, beyond critical concentrations, are harmful to plants, animals and humans. In our cities, most people breathe in dirty air with gaseous contaminants linked to varying cardiopulmonary and cardiovascular diseases, hyperactivity, neurobehavioral effects and even death (Nriagu, 1978; Massami et al., 2001; Peng et al., 2005; Osibogun, 2006).

There are several environmental concerns over particulates in the air: (i) the dirt they produce when settled on the ground is annoying and requires energy and money for removal, (ii) They produce effects that is detrimental to materials, plants and animals, including man and (iii) There is concern over their effect on the heat balance of the earth through reflection and absorption of solar radiation. These effects are complicated by the fact that many of the particulates remain aloft for unusually long periods and in some cases become permanently air-borne. Human exposures to air-borne chemicals vary widely among inhalation micro environment categories, which include workplaces, residences, outdoor ambient air, transportation, recreation areas and public spaces. There are also wide variations in exposure within each category, depending on the number and strength of the sources of the airborne chemicals, the volume and mixing characteristics of the air within the defined micro environment, the rate of air exchange between indoor and outdoor air, and the rate of loss to surfaces within the micro environment (Akanni and Solanke, 2002).

Ambient air quality monitoring in urban areas have a number of objectives. One is to generate information on the spatial and temporal distribution of air pollution in urban areas. Monitoring data are then compared against air quality standards to identify potential risks to human health or the environment. Data indicating high pollutant concentrations in certain parts of an urban area (such as a central business district) or during certain periods of the day or year (certain months) enable policy makers to take the necessary measures aimed at reducing pollution at these locations or during these periods. Biological monitoring has been defined as the systematic use of biological responses to evaluate changes in the environment with the intent to use this information in quality control programmes (Matthews, 1982). Biological monitoring is generally less expensive than other methods and is thus particularly suitable for long-term monitoring over large areas without deploying sophisticated expensive and high-level maintenance equipment. Biological monitoring of air pollutants can be passive or active. Passive methods provide a cost-effective solution for monitoring air quality by observing plants growing naturally within the area of interest at locations where continuous monitoring may not be practicable. Active methods detect the presence of air pollutants by placing test plants of known response and genotype in the study area. The response of plants to elevated concentrations of air contaminants is modified by other environmental factors and by the physiological status of the plant. Monitoring the plants directly assesses the integrated effects of these factors and contamination. It has however been noted that trees remove gaseous air pollution primarily by uptake through leaf stomata, though some gases are removed by the plant surface. Once inside the leaf, gases diffuse into intercellular spaces and may be absorbed by water films to form acids or react with inner-leaf surfaces. Trees also remove pollution by intercepting airborne particles. Some particles can be absorbed into the tree, though most particles that are intercepted are retained on the plant surface. The intercepted particle often is re-suspended to the atmosphere, washed off by rain, or dropped to the ground with leaf and twig fall. Consequently, vegetation is only a temporary retention site for many atmospheric particles. Atmospheric pollution has emerged as a problem in most African countries only in the past few decades, its severity and impacts are still largely unknown, although it is believed that gaseous pollutants and acid rain have adversely affected vegetation, soils and water in some areas. Despite this, the atmospheric chemistry of the tropics has been poorly studied in the past, placing our current understanding in doubt. In Nigeria, empirical studies have been carried out on the spatial pattern of micro climatic variables, energy distribution in urban centres, thermal responses, comparative study of urban heat island syndrome within the urban canopy (Ojo, 1978, 1981; Akanni, 1987; Ojo, 1988; Efe, 2004; Oke, 2004, 2004a) and bio monitoring of air quality (Oluwande, 1977; Osibanjo and Ajayi, 1980; Oniawa and Egunyom, 1983, 1986; Fatoki and Ayodele, 1991; Ogunsola et al., 1993; Odukoya et al., 2000 ; Obioh et al., 2005), none of the studies has examined the spatio-temporal and seasonal variations in air quality of a rapidly developing metropolis. Molina, (2002) observed that much of the technology developed in the United States and Europe can be adapted to Asian, Latin American and African cities without the ‘trial-and-error’ costs that were incurred to reduce pollution in the developed world. Studies of this nature will further enable researchers compare urban air quality characteristics within a tropical city with those of other cities in both the tropical and temperate countries and achieve a desired environmental outcome of ambient air quality that allows for adequate protection of human health and well being. Moreover, the nature of urban climates needs to be understood to be able to improve the atmospheric conditions and mitigate potential adverse effects.

Hence, this paper examines the spatial and seasonal variations in particulate pollutants concentration in urban air of Lagos metropolis, Lagos state; Nigeria, by bio-monitoring the concentration of trace elemental

Figure 1. Administrative map of Lagos showing 20 local governments.

pollutants: (Pb, Cd, Cu, Cr, Al, Zn, As, Hg, Fe, Mn, Mg) on *Terminalia catappa L (*Almond) trees leaf during the short wet and short dry seasons of 2005 and 2006.

The metropolis falls within latitude 6° 34′ N and 6° 41′ N and longitude 3° 19′ E and 3° 32′ E while the state extends from latitude 6° 23′ and 6° 57′ N and longitudes 2°42′ E and 3° 42′ E of the Greenwich Meridian. It extends over 180 km from West of Cotonou, in the Republic of Benin, to its boundary with Ogun state in the North and East, the Atlantic Ocean/Gulf of Guinea also bounds the state in the South. Lagos metropolitan area is encompassed within the core of Lagos state and located in the south western part of Nigeria. It is the largest metropolitan area and a commercial nerve centre that exemplifies the rapid rate of urbanization in Nigeria (Ayeni, 1981). A Portuguese explorer Ruy de Sequeira named the area around the city '*Lago de Curamo'* when he visited the area in 1472 (Iwugo et al., 2003). The original settlers of Lagos or 'Eko', as the indigenous population calls it, were of Benin and Awori-Eko heritage. Pre-colonial Lagos originated as fishing and farming settlement in the 17th century, owing to its physical characteristics as the only natural break for about 2,500 km along the West African coast and from 1704 -1851 it served as a major centre for slave trade. Lagos consists of a large lagoon (hence its name) and an archipelago of large islands in the lagoon. Lagos metropolis consists of two main regions: the Lagos Island and the Mainland. The original city: Isale- Eko, Ikoyi, Victoria Island and Lekki corridor are referred to as Lagos Island, while Mainland encompasses the other part of the metropolis and state. The Mainland part of the state had developed and is still developing rapidly and approaching an eventual merger with the more distant part of the Mainland. The commercial centre remains Lagos Island, which is connected to the mainland by three large bridges: Eko Bridge, Carter Bridge and Third Mainland Bridge. The more developed Mainland and Lagos Island make up what is referred to as the metropolitan Lagos. Figure 1 shows the map of the study area.

MATERIALS AND METHODS

The methodology of study involves stratified selection and identification of seven dominant land use zones and random selection of 28 almond trees from four sites on each land use selected. Dominant land use were determined from land cover features generated from the 1967 (1:50,000) topographic base maps and were overlaid with land use images of Lagos metropolis subset to an area of approximately 2,383.994 km^2 to cover Lagos and its vicinity derived from Land sat thematic mapper (TM) and enhanced thematic mapper (ETM+) data pair of December 18, 1984 and February 6, 2000, acquired from the University of Maryland free Online data services (2005) and combined with the road map to identify the different categories of land use within the metropolis. Aerial photographs of the same set (scale of 1:6,000) also covering Lagos and its vicinity, were procured for the study to get an overview of major land use in the study area and after the classification a field study was undertaken to assert authenticity of the results. An 'eTrex Venture Garmin 12 XL' GPS which display transect movements, distance and bearing when the equipment acquire enough satellite signals were used to determine the coordinates, waypoints, altitude and longitude grids of selected monitoring sites. The features identified were then grouped into

Figure 2. Location of monitoring points.

different categories and sub categories and traced out using a tracing paper. This became necessary because series of land uses were mixed within the same sampling block. The identified land uses in the study area are: Commercial zone with mixed high density residential areas (some residential, some commercial), low and medium density residential areas, industrial non-residential areas, institutional areas, acquisition/open spaces and parks, dumpsites/incinerators and transportation areas. Bio-monitoring of atmospheric pollutants concentration (Pb, Cd, Cu, Cr, Al, Zn, As, Hg, Fe, Mn and Mg) involved weekly collection of leaf samples of the dominant almond trees (*T. catappa L*) exposed to ambient air and air pollutants at an average height of 1.8 m at 28 randomly selected locations along traffic corridors and at 6 locations 250 m away from traffic corridors as control for 8 months between the short-wet season of September-October and short-dry/harmattan season of November-December 2005 and 2006. The leaf samples were collected, bagged and transferred to laboratory where the samples were oven-dried and prepared for titration and quantitative determination of elemental composition of trace metals through chromatographic separations followed by the use of atomic spectroscopic methods using the laid down principles of APCAC in gm/m^2/wk. Trace elemental concentrations were read on Bulk 200 model atomic absorption spectrophotometer (AAS) using their respective lamp and wavelength.

Microsoft excel and SPSS for windows statistical packages and GIS programme: Arc View 3.3a was used for the analysis and mapping of numerous data collected. The variations in the quantity (mass concentration) and quality (chemical composition) of atmospheric pollutants at street level along the traffic corridors was determined with Pearson correlation analysis, ANOVA and difference of mean test. The variations in the street level chemical composition of pollutants with WHO/FEPA standard was analyzed by (i) determining the percentage weekly average variations and (ii) examining the differences between the mean of total suspended particulate matter (TSP) during the wet and dry seasons with the difference of mean test and (iii) comparing the measured concentration with the national (FEPA, 1991) and WHO health based air quality standards (AQS) which provide numerical limits for different averaging periods for all criteria pollutants. Figure 2 shows the location of monitoring points.

RESULTS AND DISCUSSION

Result of laboratory analysis shows a significant seasonal variation ($P < 0.05$) in TSP, values varied from 22.36 - 29.07 mg/m^3 as against WHO Air Quality Standard (AQS)

Table 1. One sample student's t-test for dfference between mean of tsp and aqs.

One- sample statistics [a]				
	N	**Mean**	**Std. deviation**	**Std. error mean**
a. Season = wet season				
Total suspended particulate matters	28	26.0458	1.5581	.2464
a. Season=dry season				
Total suspended particulate matters	28	26.5525	1.4745	.2331

Table 2. Pollutants range along traffic corridors and control.

Pollutants	Traffic corridors range (mg/m^3)	Control points range (mg/m^3)	Percentage changes (%)
Lead	1.4 - 3.1 (1.7)	1.7 - 2.6 (0.9)	52
Cadmium	1.7 - 3.15 (1.45)	2.3 - 2.6 (0.3)	21
Copper	2.0 - 3.5 (1.5)	2.85 - 3.2 (0.35)	23
Cromium	2.1 - 3.0 (0.9)	2.3 - 2.9 (0.6)	67
Aluminium	1.03 - 2.55 (1.52)	0.9 - 1.45 (0.55)	36
Zinc	2.4 - 3.6 (1.2)	1.8 - 2.9 (1.1)	92
Arsenic	0.9 - 1.98 (1.08)	1.2 - 2.9 (1.7)	157
Mercury	0.12 - 1.3 (1.18)	0.13 - 1.4 (1.27)	108
Iron	3.06 - 3.6 (0.54)	0.5 - 2.6 (2.1)	389
Magnessium	2.1 - 3.6 (1.5)	2.4 - 2.6 (0.2)	13
Manganesse	2.65 - 3.67 (1.02)	2.3 - 2.87 (0.57)	56

of 0.05 - 0.15 mg/m^3, Sulphur-dioxide and Ozone varied from 1.1 - 1.73 mg/m^3 and 0.01 - 0.18 mg/m^3 respectively as against 0.00125 and 0.0015 mg/m^3 AQS (Table 1). ANOVA showed spatio-temporal variations in pollutants and significant correlation of traffic density with all metals studied ($P < 0.05$). Analysis of differences in air pollutants along the traffic corridors and at control show that the range for wet season values for Lead (0.9 mg/m^3) was 52.9% lower than that recorded along the traffic corridors, the range for Cadmium (0.3) was 20.7% lower, Copper (0.35) was 23% lower, Chromium (0.6) was 67% lower, Aluminium (0.55) was 36% lower, Zinc (1.1) was 92% lower, Manganese and Magnesium were 13 and 56% lower, while, Arsenic (1.7) was 57% higher, Mercury (1.27) was 85% higher and Iron (2.1) was 289% higher respectively (Table 2).

Interpretation of the pollution concentration mapped with Arc View 3.3a (GIS) package also show that the TSP concentrate more along the traffic corridors during the dry season than farther away, while the reverse occurred during the wet season. The lead values show a high level concentration (2.36 - 2.66 mg/m^3) with higher dome occurring at Ilupeju and Ikoyi during the dry season and along Ikorodu road and Ikeja Interchange during the wet season. The cadmium concentrations are evenly spread with higher concentration during the dry season and pocket concentrations along the traffic corridors. This finding corroborates Baumbach (1993), Rosa (2003), Ndoke and Jimoh (2003) and Obioh et al. (2005) assertions that traffic pollutants are higher in concentration at the roadside or median than farther away. This is observable from the pollution maps (Figures 3a and 3b) of the study area.

The space for the ambient air pollution in Lagos metropolitan areas is up to 3 meters above the ground and the concentration of 1 mg/m^3 is equal to 1.37 kg TSP and/or equivalent to the emission of 1,900-vehicle km (World Bank, 1995). The amount of TSP which formed the monthly pollution 'dome' in the study area vary from 41.24 and 32.99 kg of TSP during the dry season to 39.39 and 30.63 kg of TSP during the wet season (Table 3). This is equivalent to a monthly accumulation of 164.96 kg^1 of TSP during the dry season and 157.56 kg^1 of TSP during the wet season. Data collected during the dry periods are higher by 9 and 37%, this relatively high value exceeds the maximum allowable concentrations stipulated by the state regulatory agency (Figures 4a - f show the pollution map of Lagos metropolis during wet

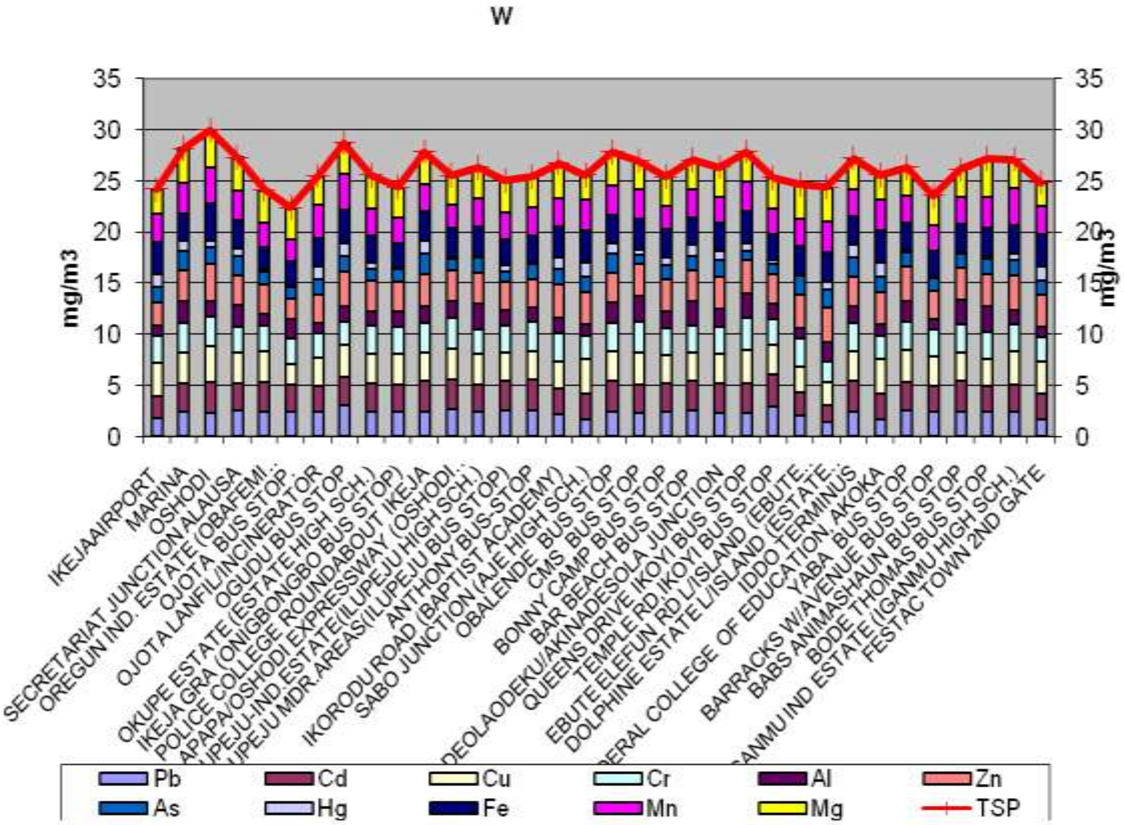

Figure 3a. Concentration of pollutants in Lagos metropolis during wet season.

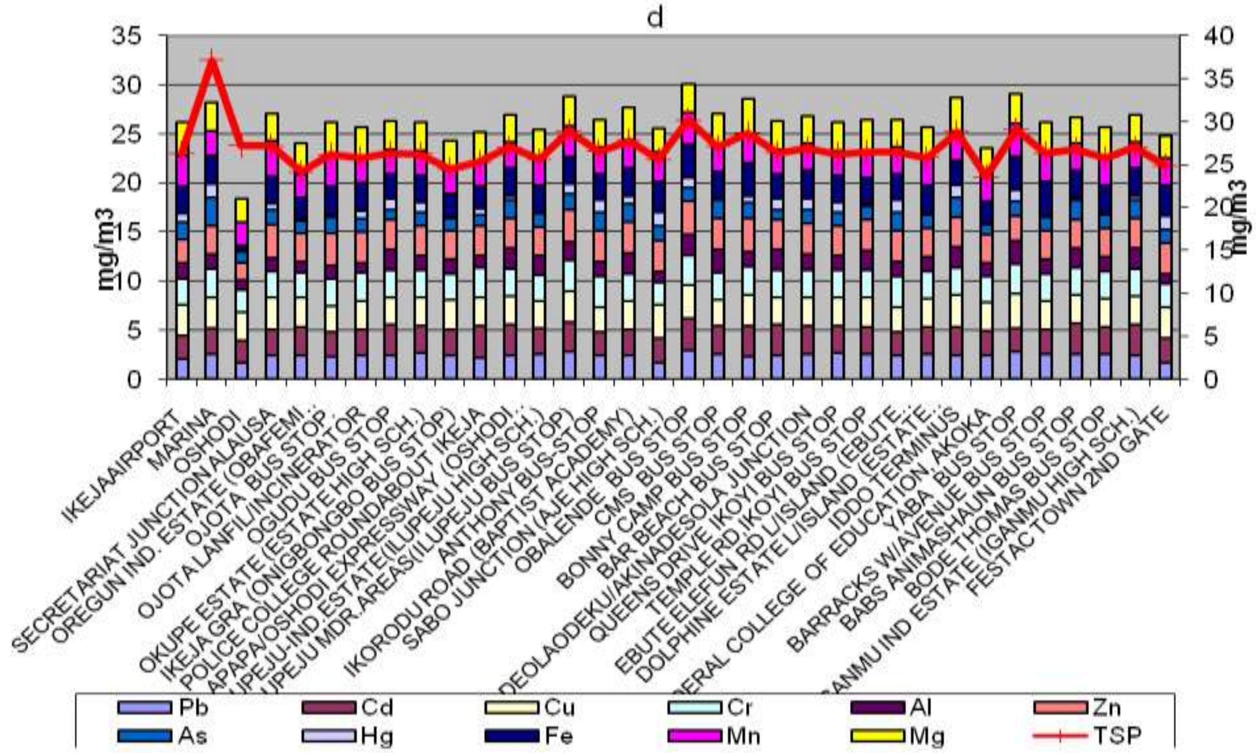

Figure 3b. Concentration of pollutants in Lagos metropolis during dry season.

Table 3. Monthly accumulation of TSP along traffic corridor during the wet and dry seasons.

		Wet season (mg/m^3)	Kg/w^1	Dry season (mg/m^3)	Kg/w^1
1	Secretariat junction alausa	27.27	37.36	27.1	37.13
2	Oregun ind. Estate	24.08	32.99	24.08	32.99
3	Ojota b/stop.	22.36	30.63	26.14	35. 81
4	Ojota landfil/incenerator	25.45	34. 87	25.68	35.18
5	Okupe estate	25.56	35.02	26.17	35. 85
6	Ogudu gra	28.75	39.39	26.31	36.05
7	Ikeja gra	24.37	33.39	24.37	33.39
8	Police college r/about ikeja	27.87	38.18	25.23	34.57
9	Apapa/oshodi expressway	25.49	34.92	26.94	36.91
10	Ilupeju-ind.estate	26.29	36.02	25.5	34.93
11	Ilupeju mdr.areas	25.05	34.12	28.83	39.50
12	Anthony bus-stop	25.42	34. 83	26.47	36.26
13	Ikorodu road	26.71	36.59	27.77	38.05
14	Sabo junction	25.55	35.00	25.55	35.00
15	Obalende	27.8	38.09	30.1	41.24
16	Cms b/stop	26.98	36.96	27.02	37.02
17	Bonny camp	25.4	34. 8	28.6	39.18
18	Bar beach	27.04	37.05	26.31	36.05
19	Adeolaodeku/akinadesola junction	26.34	36.09	26.88	36. 83
20	Queens drive ikoyi	27.85	38.16	26.17	35. 82
21	Temple rd,ikoyi	25.3	34.66	26.46	36.25
22	Dolphine estate l/island	24.36	33.37	25.76	35.29
23	Ebute Elefun rd l/island	24.67	33. 80	26.47	36.26
24	Iddo Terminus	27.23	37.31	28.73	39.36
25	Yaba b/stop	26.32	36.06	29.07	39. 83
26	Barracks w/avenue	23.55	32.27	26.25	35.96
27	Babs Animashaun	26.1	35.76	26.69	36.57
28	Bode Thomas	27.14	37.18	25.76	35.29
29	Iganmu ind estate	27.1	37.13	26.94	36.91
30	Festac town 2nd gate	24.82	34.00	24.82	34.00

and dry seasons).

Conclusion

Lagos metropolis is characterised by relatively high air pollution that varied significantly according to land use and season. Concentrations of pollutants were higherthan the WHO Air Quality Standards and were also higher along traffic corridor than further away. The monitored pollution values for wet season recordings are relatively lower in many cases than that recorded for the dry season monitoring; this from observation is due to:

(i) Lower air temperature witnessed during the wet season (25.1 - 28.8°C).
(ii) Higher wind speed along the traffic corridors (3.0 - 9.1 m/min^1).
(iii) Increase in cloud cover, increase in the number of rainfall days
(iv) Decrease in traffic volume and transit time and;
(v) Due mostly as a result of removal of bio-accumulated aerosol, trace metals and gaseous materials by rain and heavy winds.

These effluents are often deposited on roadside soils and later washed away into the nearby sewage system.

In the study area, trees also remove pollution by intercepting airborne particles. Some particles are absorbed into the tree, though most particles that are intercepted are retained on the plant surface. The intercepted particles are often re-suspended in the atmosphere, washed off by rain, or dropped to the ground as leaf and twig fall. These according to Adekola et al. (2002) and Wang (2007) increase the levels of some heavy metals in urban run-off sediments.

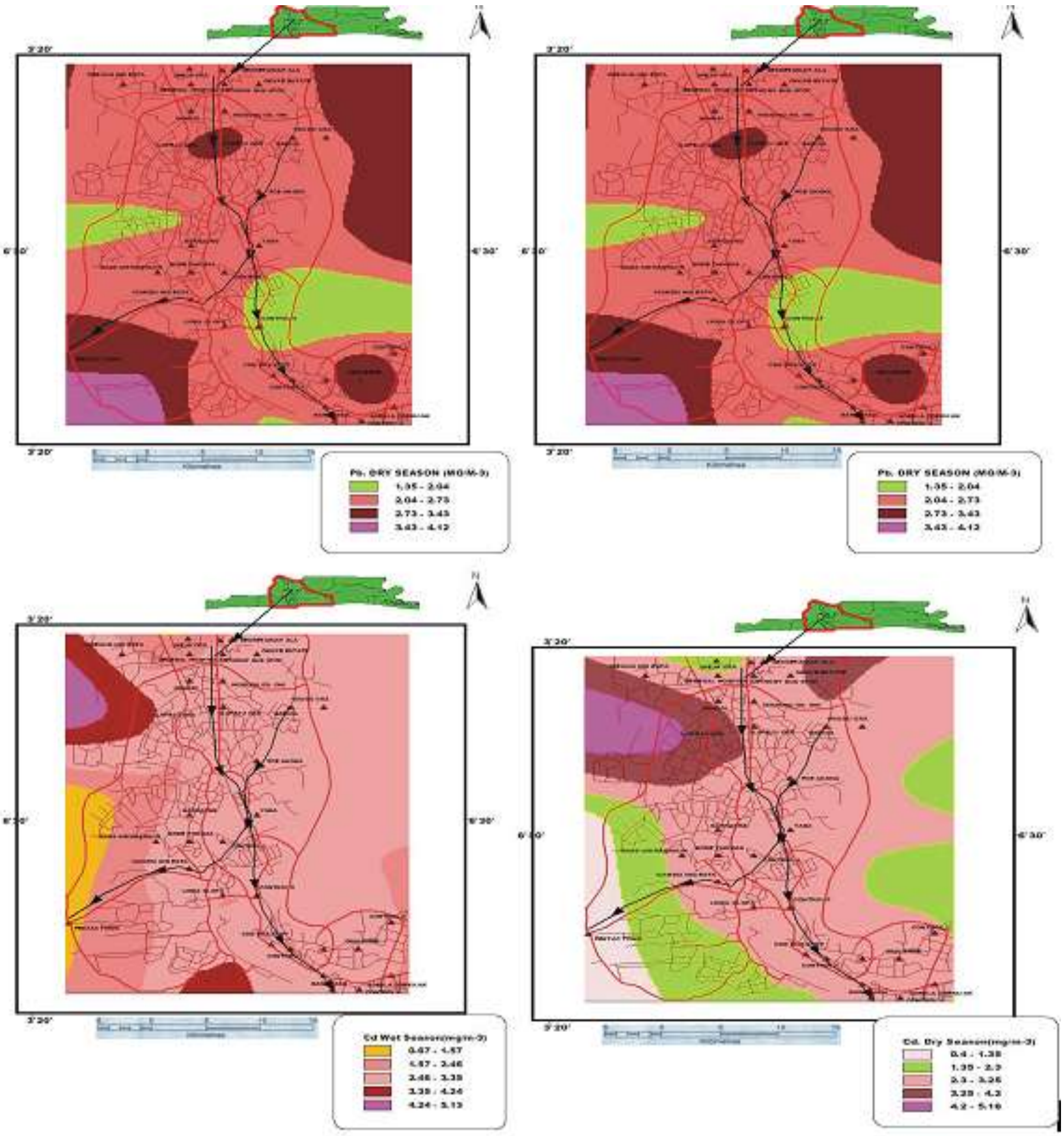

Figure 4c-f. Lead and Cadmium concentrations during dry and wet seasons.

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