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Distribution of air quality data across stratified areas of Port Harcourt metropolis

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Abstract

Distribution of Air Quality Data across seven stratified areas of Port Harcourt Metropolis was carried out. The study utilized a total of 18 parameters from four different air quality datasets obtained from 24 sampling points during field data collection. The sampling points were structured and stratified into residential, industrial, commercial, recreational, transport, dumpsite and abattoir areas. Air quality data were acquired using a multi-digital potable tool, Aerosol Gas Monitor and TESTO Gas Analyser for meteorological data, particulate matters (PM), gaseous emissions and heavy metals. Results showed that the concentrations of air quality data were not evenly distributed across the seven stratified areas, an indication of the influence of location-based activities on the distribution of air quality parameters. The minimum and maximum values of wind speed, temperature and relative humidity were obtained within Residential and Transport Areas, Abattoir and Dumpsite Areas, and, Industrial and Recreational Areas with numerical values of 1.1ms^{-1} and 3.7ms^{-1}, 27.2^{0}C and 35^{0}C, and, 67.8% and 923% for wind speed, temperature and relative humidity respectively. The values of TSP, $PM_{2.5}$ and PM_{10} ranged from 53 to 255 µg/m^3, 13 to 90 µg/m^3 and 40 to 169µg/m^3 for TSP, $PM_{2.5}$ and PM_{10} respectively with the lowest and highest values obtained within Residential and Dumpsite Areas respectively. The concentrations of NO_2 and SO_2 exceeded the standards of WHO, NAAQS and FMEnv in Industrial, Dumpsite and Abattoir Areas. Lead (Pb) showed very high values within Dumpsite Area (0.954mg/kg), Industrial Area (0.372mg/kg) and Transport Area (0.077mg/kg).

Keywords: Air Quality; Meteorological Data; Particulate Matter; Gaseous Emissions; Stratified Areas; Port Harcourt Metropolis

1. Introduction

Good air quality remains a significant factor contributing to the overall well-being of human. It is envisaged as a basic requirement needed for a healthy living [1]. This is because of the serious threat poor air quality poses to both human health and the environment. Air quality data and their distribution enable air quality expert classify and rate areas into different air quality categories. The information is equally useful in tracking the activities responsible for the release of air pollutants into the environment as well as map out strategies to contain air pollution.

Air quality assessment is the first step to air quality management. While the former focuses on the level of concentration of air pollutants, the latter is targeted at a variety of activities employed to manage and control emissions, and minimize the negative impacts of air pollution [2]. Determining air quality data remains a key to air quality management as it serves as a tool to determine the quality of air within a given locality.

Air quality data include meteorological parameters (temperature, relative humidity, wind speed and direction), particulate matters (total suspended particles, $PM_{2.5}$ and PM_{10}), gaseous emissions (oxides of nitrogen, sulphur and carbon, ozone, methane) and atmospheric heavy metals (cadmium and lead) [3, 4, 5, 6, 7].

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Air quality data of a particular region is controlled by a number of factors including the topography of an area, meteorological conditions, types of gaseous emissions and the dominant anthropogenic-related activities within the area [2]. Air quality data collection and its consequent air quality assessment and regular monitoring are becoming increasingly essential as they are a prerequisite to the management and containment of air pollution.

Anthropogenic-related activities have been linked to environmental pollution both in local and in global scale [5, 7, 8, 9, 10]. The quality of air within a given area can be impaired by anthropogenic activities. These activities include the combustion of fossil fuel (either within residential areas or in the transport and industrial sectors), gas flaring, burning of confiscated crude oil by the government agencies and the activities of illegal artisanal refining of crude oil, the latter being common practices within the Niger Delta of Nigeria. Metropolitan cities are characterized with increased rate of urbanization, industrialization and population growth which are accompanied by increased generation of enormous volume of wastes. Apart from crude oil production and illegal artisanal refinery, contributions of other anthropogenic activities to air pollution have not received proper attention and are thereby neglected and the role they play in the air quality of an area undermined. Port Harcourt metropolitan city has recently witnessed influx of humans with its consequent industrialization and urbanization. As a result, there is increased industrial activities and inflow of vehicular movement. These are contributing factors of air pollution within Port Harcourt city in addition to crude oil production and illegal refinery. Furthermore, the developmental pattern of Port Harcourt metropolitan is heterogeneous in that some residential areas are seen being sandwiched in-between industrial and commercial areas or the other way round. It has been observed that different types of land uses are associated with different pollutant generation as well as pollutant concentrations levels [11]. Therefore, air quality data can be influenced by the dichotomy between different landuse types.

Owing to the health concerns posed by air pollution and the needed global attention being given to it, daily monitoring of air quality is almost achieved in developing countries whereas in a developing country like Nigeria, it is non-existent [12]. Although data exist on the air quality of Port Harcourt Metropolis, not much has been done on stratifying the city into zones on the basis of activities being carried within the area for comparism. It has become necessary to determine the distribution of air quality data across stratified areas which have different pollutant generating activities since dominant activities within an area play a key role in determining the air quality of an area. The landuse types considered in this study include residential, industrial, commercial, recreational, transport, dumpsite and abattoir areas. The study attempted establishing the role landuse types play in air pollutant distribution.

1.1. Study area

The study was carried out within Port Harcourt Metropolis in Rivers State, southern Nigeria. The map of the study area is shown in Figure 1. It spans from the International Airport in Omagwa to Borokiri Peninsula, and from the University of Port Harcourt at Choba community to the Refinery in Eleme. Port Harcourt Metropolis lies between latitude 4^0 51’ 30’’N and 4^0 57’ 30’’N, and longitude 6^0 50’ 00’’E and 7^0 00’ 00’’E. It has an area coverage of 1,300 – 1,800 km^2 and an estimated population of over one million people [12, 13, 14, 15]. Port Harcourt is an industrial, commercial and administrative hub of Rivers State. The state is bounded with the Atlantic Ocean to the south, Akwa-Ibom State to the west, Bayelsa and Delta States to the east and, Anambra, Abia and Imo States to the north. Rivers State is relatively flat with an average elevation which ranges between 15m and 40m.

Port Harcourt Metropolis is characterized with a tropical wet climate with long, heavy wet season and short dry season [12]. Rain falls almost every month of the year with a mean rainfall value of 2,300mm [13]. Here, rainfall peaks around the months of June and September every year, thereby producing a double maxima of rainfall. A humid, moist South-West air mass commonly referred to as the Tropical Maritime air mass controls the weather of Rivers State. Although the North-East Trade Wind has a minimal effect on Rivers State, it causes harmattan between the month of December and the month of February. The two winds- Tropical Maritime and the North-East Trade Wind all play a key role in transporting and distributing air pollutants across Port Harcourt Metropolis.

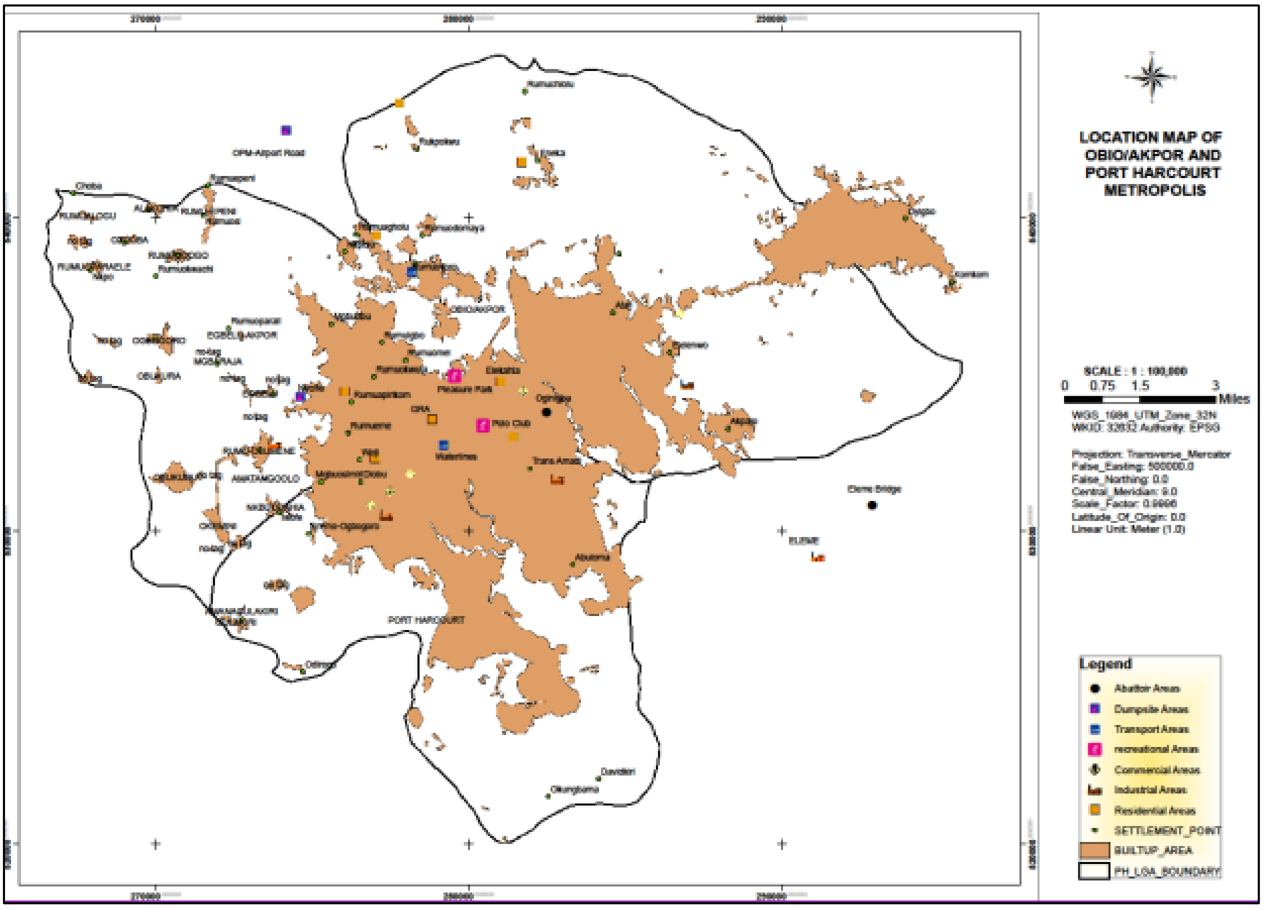

Figure 1 Location Map of the Study Area (generated from the coordinates of the Sampled Points)

2. Materials and Method

The study utilized air samples obtained during field data collection. A total of 18 parameters from four different air quality datasets (meteorological data, particulate matters, gaseous emissions and atmospheric heavy metals) were obtained from 24 sampling points. These sampling points were structured and stratified into residential, industrial, commercial, recreational, transport, dumpsite and abattoir areas with six, four, five, two, three, two and two sampling points respectively. The coordinates of the stratified areas are presented in Table 1. The air sampling tools used include a multi-digital potable tool for meteorological data, Aerosol and TESTO Gas Analysers (Table 2).

At each sampling points, the air monitoring tools were pre-calibrated and used to obtain the concentration levels of the required parameters. The detection limit was set at 0001 µg/m^3. Readings were taken thrice at a point while the average value was taken and recorded. Filed data collection was carried out in the morning hours to avoid interference. After pre-calibration of the Aerosol Gas Monitor, a volume of air was drawn into the tool through a pre-weighed filter for an 8-hour period. The meteorological parameters, gaseous emissions, particulate matters and atmospheric heavy metals obtained in the field were analysed and discussed.

Table 1 The Stratified Areas and their Coordinates

S/N	Stratified Areas	Coordinates
1	Residential	4 49 27.4 – 4 56 14.7 006 57 32.7 – 007 02 22.2
2	Industrial	4 47 06.1 – 4 48 42.9 006 56 35.8 – 007 07 00.7
3	Commercial	4 48 15.6 – 4 51 24.2

		006 59 19.1 – 007 03 57.5
4	Recreational	4 49 21.1 – 4 50 12.7 077 00 44.0 – 007 01 13.6
5	Transport	4 49 00.2 - 4 58 50.4 006 57 00.7 – 007 00 32.8
6	Dumpsite	4 48 49.3 – 4 54 27.6 006 57 48.6 – 006 57 52.9
7	Abattoir	4 48 42.9 – 4 50 13.2 006 56 35.8 – 007 02 06.4

Table 2 The Materials and Equipment used in the Study

S/N	Tools	Uses
1	Global Positioning System (GPS)	Coordinates of sampling points
2	Multi-digital potable tool	Temperature, relative humidity, wind speed and direction
3	Aerosol Gas Analyzer	Total suspended particulate matters ($PM_{2.5}$ and PM_{10}) and heavy metals (lead and cadmium)
4	TESTO Gas Analyzer	Gaseous emissions (NO_2, SO_2, CO, CH_4, O_3, H_2S, CO_2)

3. Results and Discussion

The four different datasets of air quality varied significantly across the seven stratified areas. The average concentration levels of wind speed, temperature and relative humidity are presented in Figure 2. The result shows that the minimum and maximum values of wind speed, temperature and relative humidity were obtained within Residential and Transport Areas, Abattoir and Dumpsite Areas, and, Industrial and Recreational Areas respectively. The numerical values ranged from 1.1ms^{-1} to 3.7ms^{-1}, 27.2^{0}C to 35.0^{0}C, and 67.8% to 923% for wind speed, temperature and relative humidity respectively. These average values did not vary significantly from the findings of [9]. In a research to evaluate the air quality around the vicinity of a cement factory located in Rivers State, Amah *et al.,* (2020) reported a wind speed range of 0.2 to 3.9ms^{-1}. The average minimum value of temperature (26 and 26.6^{0}C) reported in this study did not deviate from the minimum values of independently reported by [9] and [13] respectively. The range of values of relative humidity are within the range of values obtained by [9, 12, 13]. These independent researchers reported relative humidity of Port Harcourt to have ranged from 653% to 982%.

The average concentration levels of particulate matters are presented in Figure 3. The values ranged from 53 to 255 μg/m^3, 13 to 90 μg/m^3 and 40 to 169μg/m^3 for TSP, $PM_{2.5}$ and PM_{10} respectively. The lowest and highest values of TSP, $PM_{2.5}$ and PM_{10} were all obtained within Residential and Dumpsite Areas respectively. The high values of TSP in Port Harcourt Metropolis have been reported in literatures [12, 16]. Although the values of $PM_{2.5}$ are higher than the values specified by World Health Organization, WHO (25 μg/m^3) and National Ambient Air Quality Standards, NAAQS (35 μg/m^3) for ambient air quality, the $PM_{2.5}$ of 13 to 90 μg/m^3 obtained in this study are within the range of values of [9] (18 - 298 μg/m^3) and [3] (33.3 – 15.4 μg/m^3). Apart from Recreational Area, PM_{10} in other stratified areas exceeded the WHO's standard of 50μg/m^3 although these still within the range of values reported by [9] (38 – 616 μg/m^3) and [17] (193.5 - 7028.8 μg/m^3).

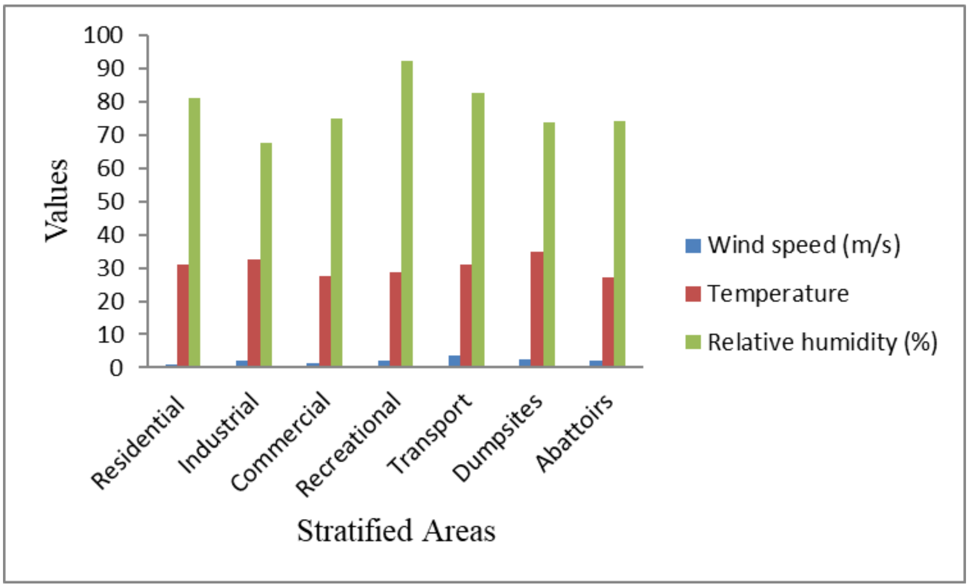

Figure 2 Average Concentrations of Meteorological Parameters across the seven Stratified Areas

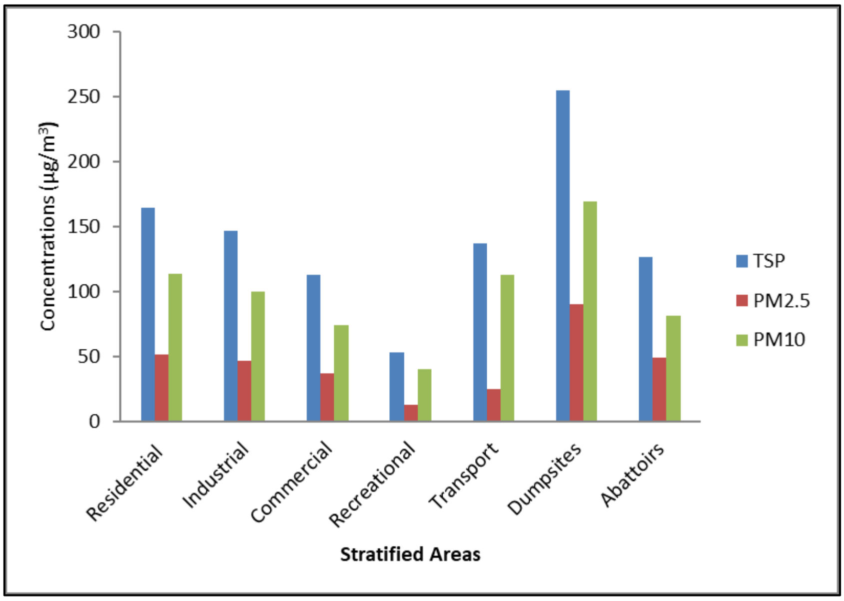

Figure 3 Average Concentrations of Particulate Matters across the Seven stratified Areas (TSP = total suspended matter, PM = particulate matter)

Figures 4, 5 and 6 are the concentration levels of gaseous emissions across the study area. The values ranged from 9ppb in Residential Area to 1,261ppb in Dumpsite Area for NO_2, 5ppb in Transport Area to 1,256ppb in Abattoir for SO_2, 19.7ppm in Dumpsite to 20.7ppm in Abattoir for O_2, 0.0ppm in Recreational Area to 2.5ppm in Dumpsite for CO, 0.10ppm in Commercial Area to 0.50ppm in Transport Area for O_3, 0.0ppm in Commercial, Recreational and Transport Areas to 0.15ppm in Dumpsite for CH_4, 0.0ppm in Residential, Industrial, Commercial, Recreational and Transport Areas to 0 5ppm in Dumpsite for H_2S, and, 0.6ppm in Abattoir to 238.2 in Recreational Area for CO_2. NH_3 was only detected within Dumpsite Area with an average value of 0.2ppm. The concentrations of NO_2 exceeded the standard of WHO (40-60 ppb) in Industrial, Dumpsite and Abattoir Areas whereas the concentrations of SO_2 exceeded the standards of WHO (2ppb), NAAQS (140ppb) and FMEnv (150ppb). The results of gaseous emissions are similar to the findings of [3], [12] and [17]. Whereas [3] and [17] reported higher values of NO_2 and SO_2 in some parts of Port Harcourt, [12] showed that H_2S, NH_3 were not detected within the study area.

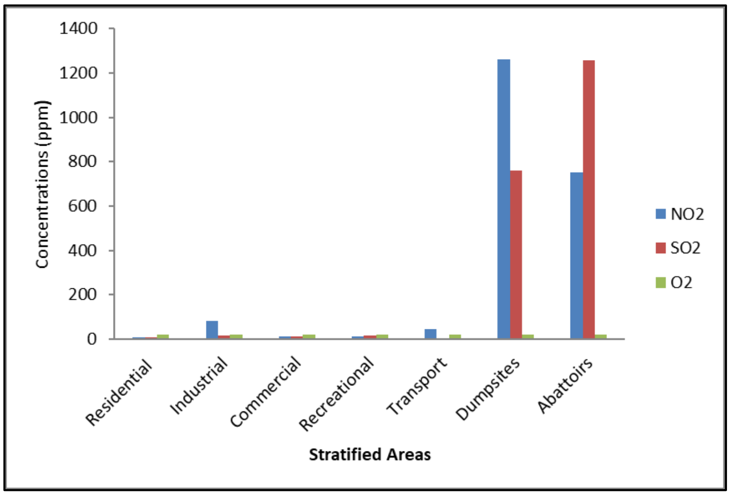

Figure 4 Average concentrations of Gaseous Emissions across the Seven stratified Areas (NO_2 = nitrogen dioxide, SO_2 = sulphur dioxide, O_2 = oxygen)

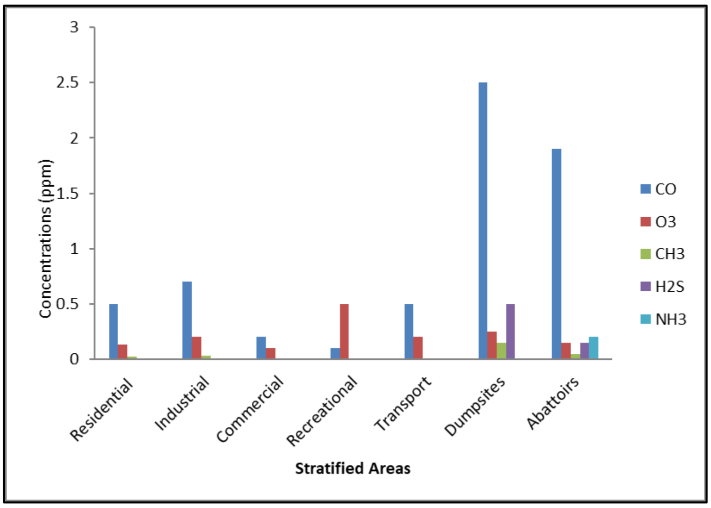

Figure 5 Average concentrations of Gaseous Emissions across the Seven stratified Areas (CH_4 = methane, O_3 = ozone, CO = carbon monoxide, H_2S = hydrogen sulphide, NH_3 = ammonia)

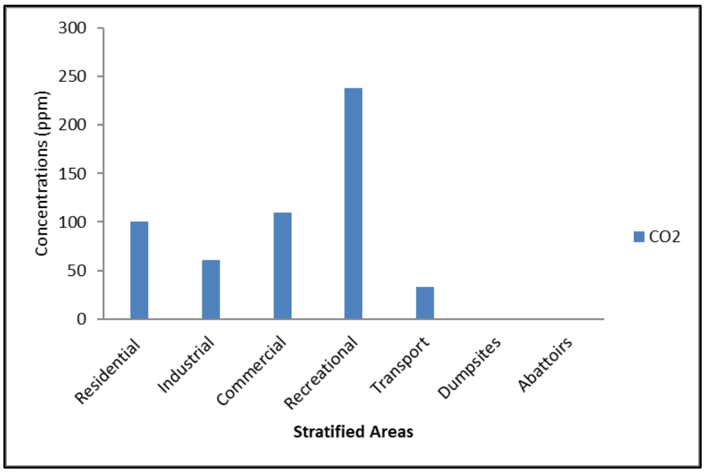

Figure 6 Average concentrations of Carbon dioxide (CO_2) across the Seven Stratified Areas

Heavy metals whose occurrence in the air is attributed to the combustion of fossil fuel were considered in this study. The concentrations of cadmium (Cd) and lead (Pb) varied significantly (Figure 7). The concentrations of Pb were very high in Dumpsite Area (0.954mg/kg), Industrial Area (0.372mg/kg) and Transport Area (0.077mg/kg). The minimum and maximum concentrations of Cd and Pb were obtained within Recreational and Abattoir Areas, and, Recreational and Dumpsite Areas respectively.

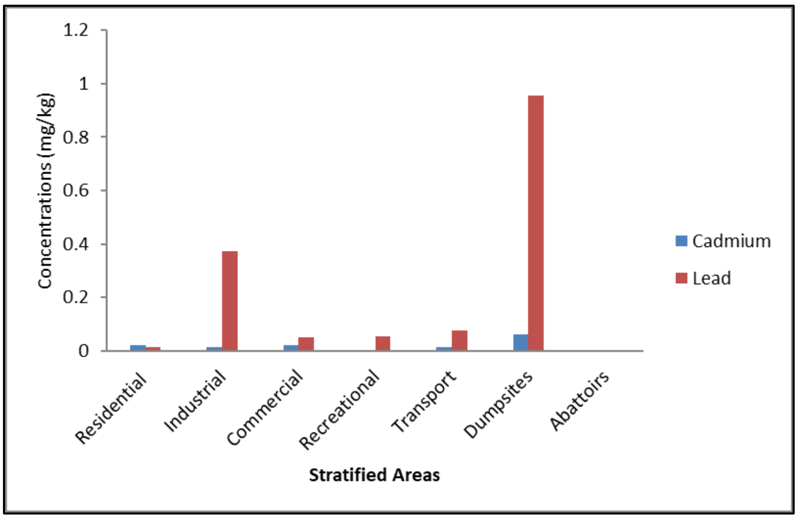

Figure 7 Average concentrations of Cadmium (Cd) and Lead (Pb) across the Seven Stratified Areas

4. Conclusion and Recommendation

The concentrations of air quality data were not evenly distributed across the seven stratified areas studied. All the stratified areas show high concentrations of O_3. CO concentrations are high in all the stratified areas except Recreational Area whereas $PM_{2.5}$ concentrations are high in all the stratified areas except Recreational and Transport Areas. Pb has very high concentrations within Industrial, Dumpsite and Transport Areas, an implication of the impact of the use of fossil fuel. The study found that landuse types have a control on the distribution of air quality within Port Harcourt metropolis. All the air quality data analysed for are present within the dumpsite area it is recommended that proper waste management should be employed.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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