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Assessment of Air Quality Characteristics across Various Land-Uses in Port-Harcourt Metropolis

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Abstract

Over the years both globally and locally, anthropogenic actions and urbanization, have been linked to environmental pollution and the consequent health effects therefrom. This study as a result, assessed the air quality characteristics in comparison with air quality standards, in Port-Harcourt metropolis. The study adopted the quasi-experimental research design. Primary data for air pollution, rainfall, and temperature were collected across the various land-uses in the study area using Aero-Qual S500, thermometers, rain gauges for a period of six months. While secondary data were collected from the various air quality standards. However, data analyses were executed using, analysis of variance, paired t test, and descriptive statistics. Results showed that, air quality in all the land-uses, were higher than permissible limits with the built-up land-use presenting highest pollution rates (O_3, 125>100 μg/m^3; NO_2, 245>200 μg/m^3; SO_2, 27>20 μg/m^3; H_2S, 4> ±0.2-2 μg/m^3; CO_2, 987>400 PPM; $PM_{2.5}$, 33>25 μg/m^3; PM_{10}, 54>50 μg/m^3). ANOVA showed that there is a significant variation in air quality characteristics among the various land-uses at $p<0.05$. Paired t test revealed that, there is a significant difference in air quality characteristics both at wet days and dry days at $P<0.05$. As a result of findings, it is strongly recommended that, illegal refining of petroleum products be stopped and policed, while government is advised to commence planting of trees and to develop an integrated system to manage air pollution in Port-Harcourt metropolis.

Keywords: Gases; Air-quality; Land-Use; Assessment; Port-Harcourt

Introduction

One of the major challenges that plague cities especially in the developing world is sanitation [1,2]. As a result the world leaders have always attended to it as a major issue [3,4]. The reason for this generated attention includes but not restricted to; the health impacts [5] it can causes, environmental deterioration, risk of loss of life via accidents, breeding ground for mosquitoes and rodents which in turn have severe consequence for human health [6].

On the other hand, the World Health organization (WHO), classifies air pollution among one of the leading cause of environmental risks and possible deaths. It is estimated [7,8] that, about 3million deaths occur annually as a result of exposure to ambient air pollution. Much recently a study [9] identified that, about 11.6% of deaths globally is associated with air pollution; and about 94% of these deaths occurred in the developing countries. This means that the dangers associated with ambient air pollution are grave. Therefore, high amounts of gases and particulate matters such as O_3; NO_2; SO_2, H_2S, CO_2, $PM_{2.5}$, and PM_{10} pollutes the atmosphere, cause harmful effects to environment & human health; and renders the environment un-safe for habitation [10,11].

An awareness of the dangers associated with these pollutants, results in developed countries designing environmental and social frameworks with which to cater for pollution and the citizenry [12-16]. This has resulted in setting up of agencies, legal frameworks, [17] and health schemes to cater for citizens who may be exposed to anthropogenic pollution [18]. Similarly, summits, conferences, colloquy, and interactive sections are held regularly, for to inform, and sensitize the people, what the dangers of their actions would mean for the larger society [19].

Nevertheless, a large contrast is experienced in Nigeria in particular and Africa in general; where pollution is treated with flippancy. Nothing serious is happening, although a lot of propaganda is being made at various media, the lack of will to-do on the part of government and populace, has left Africa an endangered zone, where large number of people are subjected to health risks resulting from anthropogenic pollution daily [20,21]. Worst still, there are very few data sources available for to get information regarding pollution and deaths associated with pollution. This has left large number of the citizenry on the fence regarding the dangers of anthropogenic air pollution [22]. Also, the politics of air pollution is rampant; where people are treated differently due to their social, political, religious and ethnic affinities, when it comes to application of pollution laws and sanctions. Also land-use are not planned for or structured; in which case people are allowed to site their residential buildings around industrial ones or vice-versa. Some of these industries are not built with the health of the environment in mind. The implication of these is that, ambient air pollution problems have continued to mount unabated [23].

In Port-Harcourt, the problem is not different; pollution is a topical issue of major concern. In fact Weli and Ayoade [21] identified that, whether in the dry season or rainy season pollution rates are significantly higher than the world health standards. Similarly, it does not matter whether or not the place of reference within Port-Harcourt is rural or urban in land-use [21]. This implies that the drivers of pollution rates within the region are same. However, the factors responsible for the pollution rates experienced are; rickety vehicles with associated discharge of exhaust smoke; the issues of slash and burn practices [21] within the rural land uses; use of generating sets; waste incineration; and more recently illegal refining of petroleum products. Studies have been carried out in the area to unravel the problem of anthropogenic air pollution [24-28] and in their concluding remarks suggested a continuous investigation of the pollution problems in the area. Other studies have looked at the quality of rain and dew water. For example Beysens, Lekouch, Mileta, Milimouk, & Muselli, [29] investigated dew and rain water collection in South Croatia. Beysens, Muselli, Nikolayev, Narhe, & Milimouk [30] attempted Measurement and modelling of dew in islands, coastal and alpine areas. While, Beysens, Ohayon, Muselli, & Clus, [31] identified the chemical and biological characteristics of dew and rain water in urban coastal area of Bordeaux, France. What is lucid is that these studies did not identify the effects of land uses on rain and dew water pollution, neither were they carried out in the same region where the current study was carried out. This study is thus set out to assess the air quality characteristics across various land-uses in port-Harcourt Metropolis.

Material and Methods

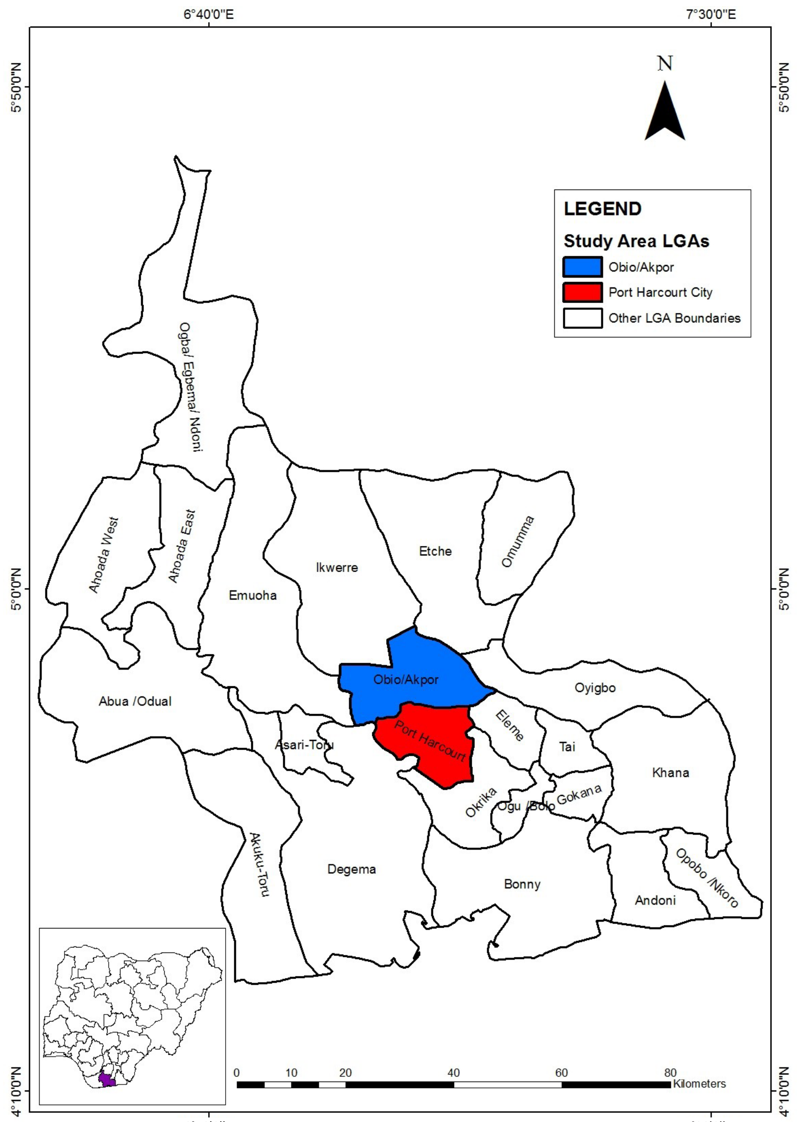


Figure 1: Rivers State showing port-Harcourt Metropolis

The study was carried out in Port Harcourt Metropolis, Rivers State, Nigeria which is located on latitudes 4°51' 30"N and 4° 57' 30"N and longitudes 6°50' 00"E and 7°00' 00"E (Figure 1). Meanwhile, Rivers State in which port-Harcourt is located is bounded on the south by the Atlantic Ocean, west by Bayelsa and Delta States, north by Imo, Abia and Anambra States and east by Akwa Ibom State (Nwanyawaa).

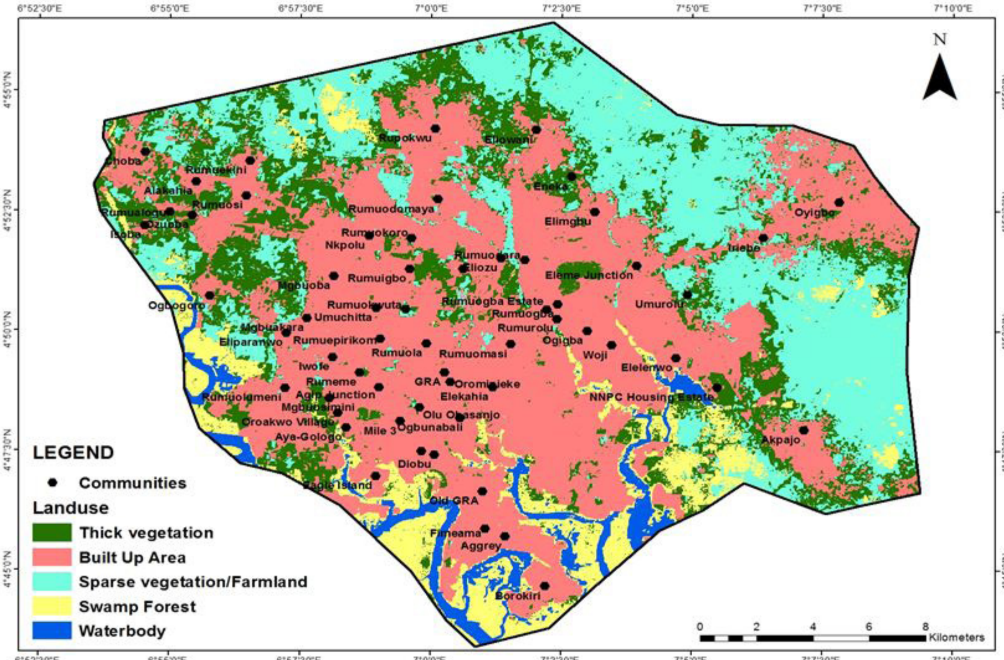
In terms of topography, the uplands range between 15 and 40m above the sea level while the mean elevation of about 15m is found in the riverine areas (Google Earth). The study area which is situated in the Niger Delta region has a relatively flat terrain with marked absence of hills that rise above the general land surface (Albert).

Port Harcourt Metropolis is found in the sub-equatorial region. It has a tropical climate with a mean temperature of 30 °C a relative humidity of 80% - 100%, and a mean yearly rainfall of about 2,300mm [32]. The predominant Air Mass System in Rivers State is the Tropical Maritime Air Mass (mT). This air mass is humid, moist and brings rainfall into this environment and popularly called the SW Monsoon Wind. The influence of the Tropical Continental (cT) air mass is minimal and it brings harmattan between December and February and referred to as the NE Trade Wind. These air masses are thought to have some influence on the pollution distribution in port-Harcourt.

Tropical rainforest is found in the inland part of Rivers State and mangrove swamps towards the coast the Atlantic Ocean. The vegetation represents the most luxuriant, the most complex, and the most diverse terrestrial ecosystem the world has known [33]. Unfortunately, much of the rainforest has been destroyed as a result of farming, commercial lumbering and urbanization; ironically these vegetal covers are supposed to serve as sink to pollutants, wherein they are depleted pollution levels are projected to be on the high. According to the last census in 2006, Port Harcourt has a total of 1,382,592 when projected with 5.5% growth rate annually the total population is expected to be 2,066,975 [34]. Just like other cities in the Niger Delta, the capital city of Rivers State, Port Harcourt has witnessed tremendous growth in its population, since its inception. The major factor of this population growth include the boom of the oil industry and oil servicing industries which attract many people from different towns within and outside Nigeria. This increasing population, have to contend for the resources and land space on one hand and on the other, their activities have propensity to increase pollution rates especially in the presence of poor regulations.

This study adopted the quasi-experimental research design and primary and secondary data were used for the study. Primary data for air pollution, rainfall, wind speed, relative humidity and temperature were collected across the various land-uses in the study area using Aero-Qual S500, thermometers, rain gauges for a period of six months. On the other hand, the secondary data were permissible limits for the various gases generated from the records of World Health Organization (WHO) and Nigeria's Federal Ministry of Environment (FME).

However, the researcher attempted a reconnaissance survey so as to familiarise and ground-truth present state of the land-uses in the study area. Again, sample locations were selected based on land-use types using stratified random sampling technique. This sampling technique was used because it has high statistical precision and the variability within the subgroups is lower compared to the variations when dealing with the entire population [35]. The major land-use types of Port Harcourt Metropolis made use of include thick vegetation, built up area, sparse vegetation/farmland and fresh water swamp [36] (Figure 2).



Sources: Modified after Eludoyin and Akinola [36]; United States Geological Survey

Figure 2: Landuse of Port Harcourt Metropolis

The built up area was further divided into industrial, commercial, residential (low and high) and peri urban/rural land-use types. This categorisation has also being used by Weli [37]. The area in square kilometre generated in the study of Eludoyin and Akinola [36] was used to proportionally generate the number of sampling locations for the study. The land-use types in the built up area were given equal treatment by giving each land-use type equal number of sampling locations. In order to select the sample points which served as study monitoring stations for air quality and meteorological parameters, the land use map of the study area were gridded into 1000m x 1000m (1000000 square meters or 1square kilometre) and each grid were coded in their respective land use type [38]. However, 5% of the total grids in each land-use type were randomly selected for the data collection. As a result, the number of sampling locations with respect to each land-use is as displayed in Table 1. The latitudes and longitudes sampling stations were there after obtained with the aid of a GPS.

Land-use types	Sub Divisions	Area (Sq. km)	No of Possible Sampling Locations based on 1000m x 1000m Grid	5% of the Sampling Locations
Thick vegetation		81.76	82	4
Built up area	Commercial Industrial Peri-Urban/ Rural Low Residential High Residential	205.89	206	2 2 2 2 2
Fresh water swamp		42.70	43	2
Farmland/Sparse vegetation		111.55	112	6
Total				22

Table 1: Sampling Locations across Different Land-use Types in Port Harcourt Metropolis

Rain-gauges were used to collect rain water from each of the land-use types. However, rain water was collected for 6 months simultaneously with the collection for the GHGs; although the periodization took into account the drier period (November, December & January) and the wettest period (June, July & August) [37]. The intension to do a dry and wet season compare, arose from the fact that the researchers wanted to unravel the influence of meteorological controls on the dispersal of pollutants.

Air quality parameters to be investigated included Nitrogen dioxide (NO_2), Sulphur dioxide (SO_2), Methane (CH_4), Hydrogen sulphide (H_2S), Carbon monoxide (CO), Particulate matter ($PM_{2.5}$, and PM_{10}) and Ozone (O_3). Air quality samples were taken in the same sample points where weather data were collected and at meteorological hours such as 9:00 hrs and 15:00 hours using aero-qual multigas monitor 500 Series which has also been used by Weli and Obisesan, [39] and Weli and Itam, [40] with varying levels of success.

In terms of data analyses descriptive and inferential statistics were utilized for the study. The descriptive statistics was used to explain the mean values of data generated. Analysis of Variance (ANOVA) was used to test if there was a significant variation in air quality characteristics among the various land-uses at 0.05 level of significance. While the paired t test was used to test for difference in air quality characteristics both at wet days and dry days at 0.05 level of significance. These analyses were performed using Statistical Package for Social Scientist (SPSS) version 22.0.

Results and Discussion

In Table 2 the average distribution of meteorological parameters across the study area is shown. In the table, the different land uses have recorded different values for specific weather parameters measured. For instance, in the wet period, average rainfall for thick vegetation land-use was 8.5 inch, whereas, the amount recorded for built-up areas is 8.5 inch. Fresh water swamp recoded an average rainfall amount of 8.32 inch and farm land/sparse vegetation, recorded an average rainfall amount of 8.4 inch. However, for temperature, the built-up areas recorded the highest average temperature of 26.2 °C, while the fresh water swamp and thick vegetation land uses recorded an average temperature of 26 °C respectively. Also, wind speed appeared to be higher in the farm-lands (2.78 km/hr), while the thick vegetation recorded the lowest average wind speed/ hour of 2.55 km/hr. Nevertheless, relative humidity was highest in the built-up environment of the study area with a value of RH/88.5%, while thick vegetation recorded the lowest with RH/84.9%.

On the other hand in the dry period, the different land uses also recorded different values for specific weather parameters measured. For instance, average rainfall for thick vegetation land-use was 0.85 inch, whereas, the amount recorded for built-up areas is 0.9 inch. Fresh water swamp recoded an average rainfall amount of 0.89 inch and farm land/sparse vegetation, recorded an average rainfall amount of 0.9

inch. However, for temperature, the built-up areas recorded the highest average temperature of 27.7 °C, while the fresh water swamp and thick vegetation land uses recorded an average temperature of 27 °C and 27.1 °C respectively. Also, wind speed appeared to be higher in the farm-lands (1.28 km/hr), while the thick vegetation recorded the lowest average wind speed/hour of 1.18 km/hr. Nevertheless, relative humidity was highest in the built-up environment of the study area with a value of RH/83.7%, while thick vegetation recorded the lowest with RH/81.8%. The reasons for these weather characteristics observed is no farfetched. The region is a tropical coastal environment, which is affected by the onshore moving winds arising from the Atlantic. Also, the human activities in the area is seen to affect the not only the temperature characteristics but also the buoyance of the wind system.

S/N	Land-uses	Wet period				Dry period			
		Rainfall (inch)	Temperature (°C)	Wind speed (Km/h)	Relative/H (%)	Rainfall (inch)	Temperature (°C)	Wind speed (Km/h)	Relative/H (%)
1	Thick vegetation	8.2	26	2.55	84.9	0.85	26,9	1.18	81.8
2	Built up area	8.5	26.2	2.65	88.5	0.9	27.7	1.26	83.7
3	Fresh water swamp	8.32	26.1	2.64	87.6	0.89	27	1.21	82.1
4	Farmland/Sparse vegetation	8.4	26	2.78	87.9	0.9	27.1	1.28	83.1

Table 2: Average distribution of meteorological parameters across the study area

Land-uses	Concentration of atmospheric pollutants in µg/m³ and PPM compared with WHO standards						
	O_3	NO_2	SO_2	H_2S	CO_2	$PM_{2.5}$	PM_{10}
Thick vegetation	118.5>±100	239.8>±200	26>±20	4> ±0.2-2	635>±400	30.1>±25	52.5>±50
Built up area	125>±100	245>±200	27>±20	4> ±0.2-2	987>±400	33>±25	54>±50
Fresh water swamp	122.5>±100	243.3>±200	26.5>±20	3.78> ±0.2-2	856.9>±400	32>±25	52.2>±50
Farmland/Sparse vegetation	124>±100	240>±200	26.5>±20	3.56> ±0.2-2	758>±400	32>±25	53>±50

Table 3: Average concentration of atmospheric pollutants across various land-uses in the study area

In Table 3, concentrations of the atmospheric pollutants are revealed. From all the values realised one thing is lucid; that is, all areas in the study area are polluted regardless the use to which land is put. This is because; all the land uses investigated posted values that are higher than the world health organisation standards (W.H.O). However, the area most hit with pollution problem is the built-up environment. In this land use, the average pollutant rates were as follows: O_3 ± 125 µg/m³ of which the permissible limit for O_3 is ±100 µg/m³. In the same vain NO_2 observed was ±245 µg/m³, which is higher than the permissible limit of ±200 µg/m³. Observed SO_2 was ±27 µg/m³, which is also higher than the WHO permissible limit of ±20 µg/m³. Observed H_2S was ±4 µg/m³, which is higher than the permissible limit of ±0.2-2.0 µg/m³. CO_2 amount observed was also very high for the built-up areas with value of ±987 µg/m³, which is higher than the permissible limit of ±400 µg/m³. Particulates, were also very high, when compared with the WHO standards as they posted; $PM_{2.5}$=33>±25 µg/m³ and PM_{10} 54>±50 µg/m³. However, the factors responsible for this include that, apart from the effects of the illegal mining of petroleum products along the coast-lines of the area, there is also the problem of fumes from vehicles, machines, and generators in the built up environment, with no corresponding vegetal covers to ameliorate the situation of the emitted gases. This finding however is in tandem with that of earlier researchers [11,16,22], who asserted that most of the urban dwellers are subjected to serious air pollution problems due in part to the problem of anthropogenic emissions.

Gases	F	Sig	Remark
O_3	132.2	0.001<0.05	Significant
NO_2	141.1	0.000<0.05	Significant
SO_2	78.5	0.041<0.05	Significant
H_2S	134.3	0.002<0.05	Significant
CO_2	158.4	0.000<0.05	Significant
PM_{10}	245.1	0.000<0.05	Significant
$PM_{2.5}$	45.4	0.000<0.05	Significant

Table 4: Summary of the ANOVA models for comparison of pollutants among the various land-uses

In Table 4, the analysis of variance models for gases and pollutants are significant and as follows: O_3 (F132.2; $P<0.05$), meaning there is a statistical significant difference in O_3 concentration across the various land uses in the area. NO_2 (F141.1; $P<0.05$), meaning there is a statistical significant difference in NO_2 concentration across the various land uses in the area. SO_2 (F78.5; $P<0.05$), meaning there is a statistical significant difference in SO_2 concentration across the various land uses in the area. H_2S (F134.3; *P<0.05*), meaning there is a statistical significant difference in H_2S concentration across the various land uses in the area. CO_2 (F158.4; *P<0.05*), meaning there is a statistical significant difference in CO_2 concentration across the various land uses in the area. PM_{10} (F245.1; *P<0.05*), meaning there is a statistical significant difference in PM_{10} concentration across the various land uses in the area. $PM_{2.5}$ (F45.4; *P<0.05*), meaning there is a statistical significant difference in $PM_{2.5}$ concentration across the various land uses in the area. However, the catalyst for this spatial variation in distribution of pollutants are the meteorological controls (Weli & Ayoade; Weli & Obisesan)[21,39]; the variation in anthropogenic activities due to land use (Zhu, *et al.*; Salami, Subramani & Okhumode) [25,26]. However, the study disagrees significantly with the findings of Obunwo, and Nkeremechi [7] and Kan, et al. [8], who sited elevation as a cause for spatial variation in distribution of pollutants, as the area is generally a flat terrain.

Gases	T	Sig	Remark
O_3	234.3	0.000<0.05	Significant
NO_2	211.5	0.004<0.05	Significant
SO_2	112.4	0.001<0.05	Significant
H_2S	231.1	0.003<0.05	Significant
CO_2	124.3	0.002<0.05	Significant
PM_{10}	131.6	0.003<0.05	Significant
$PM_{2.5}$	132.4	0.000<0.05	Significant

Table 5: Summary of the paired 't' test analyses, of the comparison of pollutants at both dry and wet seasons

However, in Table 5, evident is the fact that the concentrations of pollutants are different in seasons as elucidated by the paired t test statistics: O_3 (t=234.3; *P<0.05*), meaning there is a statistical significant difference in O_3 concentration both in the wet and dry periods in the area. NO_2 (t=211.5; *P<0.05*), meaning there is a statistical significant difference in NO_2 concentration across the various land uses in both dry and wet periods in the area. SO_2 (F112.4; *P<0.05*), meaning there is a statistical significant difference in SO_2 concentration across the various land uses in both the dry and wet periods in the area. H_2S (F231.1; *P<0.05*), meaning there is a statistical significant difference in H_2S concentration across the various land uses in the area both in dry and wet periods. CO_2 (F124.3; *P<0.05*), meaning there is a statistical significant difference in CO_2 concentration across the various land uses both in the wet and dry periods in the area. PM_{10} (F131.6; *P<0.05*), meaning there is a statistical significant difference in PM_{10} concentration across the various land uses in both the dry and wet periods in the area. $PM_{2.5}$ (F132.4; *P<0.05*), meaning there is a statistical significant difference in $PM_{2.5}$ concentration across the various land uses in both the dry and wet periods in the area. This implies that, the seasons have significant influence on the pollution rates in the study area, as corroborated by Weli and Ayoade [21].

Recommendations and Conclusion

This study has identified that, pollutant concentration in the study area is high regardless of the land use. This particular phenomenon of air pollution is going to have severe consequences for the local dwellers and the dwellers in the adjoining states if nothing is done to abate air pollution concentration in this area. As a result, the following recommendations are advocated: There is immediate need to create awareness in the study area for to educate the locals on the implications of their daily actions on the environment. This awareness campaign should be carried out using local languages; involving the chiefs and traditional rulers as co-facilitators. Similarly, illegal refining of petroleum products be stopped and policed adequately, as the local refining of petroleum products is perceived to be one of the major contributors to the pollution rates in the study area. Also, the government, non-governmental organizations, cooperate bodies and individuals are by this study advised to commence planting of trees and to develop integrated systems to manage air pollution in Port-Harcourt metropolis. Furthermore, nose mask and eye sun shade glasses are recommended for persons who have daily exposure with the ambient air in Port-Harcourt.

In conclusion, arising from the findings of this study and the health and other environmental risks associated with high rates of pollution there is the need to investigate the health effects of air pollution in the area, which is a limitation of this current study. As such diseases associated with air pollution such as asthma, obstructive pulmonary diseases, and damage lungs tissues, respiratory tract infections should be taken inventory of. Similarly, there is need for regular medical checkup for individuals living in the study area.

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