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Assessment of Heavy Metal Concentration of Aerosol in Residential and Commercial Areas around Port Harcourt Metropolis, Rivers State, Nigeria

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Abstract

This study examined the heavy metal concentration of aerosol and its perceived impact on the health of residents of Port Harcourt Metropolis. From the study area, six locations on the Total Suspended Particulate (TSP) in the atmospheric aerosol was sampled, two sample locations in each of High Density Residential (HDR), Moderate Density Residential (MDR), and Low Density Residential (LDR). Offline aerosol measurement was carried out for seven days (a week) during wet and dry seasons. 84 aerosol samples were collected and subjected to laboratory analysis for selected heavy metals. ANOVA, T-Test, and Chi-Square analysis were used in the analysis of the data on the SPSS software. The findings indicated that there is no statistically significant variation in the concentration of the selected heavy metals across locations and the Days of the (DO) week. In the study area, there are variations in the concentration of Copper (Cu), Nickel (Ni), and Iron (Fe) in the TSPM across the seasons while there is no statistically significant seasonal variation in the concentration of Chromium (Cr) and Lead (Pb) in the study area. The distributions of every other metal in the TSP except Fe in all the sampled locations are the same. LDR and MDR are similar in relation to average concentration of Fe (ppm) while MDR and HDR are also similar belonging to the same group. In the study area as revealed by the findings further showed that there is a statistically significant difference in the perception of residents of health risk associated with TSP in the atmosphere. Conclusively, that aerosol concentration is not static but dynamic across Land use types. Hence, the study recommends the need for source identification and apportionment using receptor models in new studies.

Keywords: Atmosphere, Heavy Metal, Aerosols, Residential, Commercial.

1. Introduction

Air pollution has been a global environmental health challenge. Both urban and rural areas have particles that are suspended in their atmosphere. As far as measures taken to reduce emissions are insufficient, urban areas have a high level of air pollution. A lot of effort has been dissipated by different researchers across the globe to ascertain and also quantify the health implication of poor air quality. Aerosol is a key component of air pollution. With highly variable chemical composition, and size distribution, atmospheric aerosol is suspension of liquid, solids or mixed particles (Putaul, 2010). They are solid or liquid particles with diameter of approximately 0.002-10μm. They vary in their chemical composition and size distribution. This is as a result of their numerous sources having different mechanism of formation. It has been a great health concern on global scale regarding the urban air quality. Air pollution has been of special interest especially in urban areas as a result of persistent high concentration of aerosol, coupled with air pollution and its health effect on humans, (Romieu et al., 2012).

Human activities introduce air pollution into the atmosphere which changes the natural state of the environment. Millions of people worldwide according to Shi (2015) have been influenced by air pollution. Air pollution, impacts negatively on the climate public and individual health. This leads to increase in morbidity and mortality rate (Abbas, 2009; Maier et al., 2000). The world's greatest problem is increase in the mortality and morbidity arising from air pollution as it impacts on the climate change and also on both individual and public health. Many air pollutants are responsible in causing ailment in humans. For instance, in Nigeria, sources of urban air pollution include local scales, domestic wood burning fires, vehicular emissions and industrial gas flaring (Ravindra et al., 2008) and these have health effects on humans. Long term effect of aerosol on human health includes such things as acute pulmonary problems which may consequently lead to hospitalization and premature death of the individual. Other long-term effects of aerosol include cancer, chronic respiratory problems, and low birth weight (Lawal, 2015). Aerosol, on the regional scale, diffuses from the region of high concentration of its emissions to regions of relatively clean atmosphere (low concentration in its emission (Zhang et al., 2012). Again, poor air quality is worsened by motorbike riders or what is popularly known as Okada. Regulatory bodies are lagging behind in implementation of policies that reduce emissions to the atmosphere. There is also the problem of lack of enforcement of worthy vehicles on the road, and this leads to toxic exhaust emissions into the atmosphere. There is also the problem of lack of enforcement of land zoning which entails location of industrial activities in areas that are populated (Lawal, 2015).

Urban areas with rapid land cover and residential density changes, suffer significantly from human activities. Humans introduce pollutants into the atmosphere and this changes the heavy metals concentration of the atmosphere which may likely negatively impact on human health. Studies done on aerosol showed that different components of aerosol exist which among others include Particulate Matter of different sizes, soot, heavy metals and these constitute very heavy havoc to the health of the populace. These components of aerosol have been studied but none has been done on the heavy metal concentration of aerosol. Even if studied in such places as China and Europe there exists a locational gap that needs to be closed. This study seems to address this gap thereby filling the missing gap in the air quality dataset.

Global modelling combined with epidemiological exposure- response functions indicate that ambient air pollution causes more than four million premature deaths per year" (Kim et al., 2015). Different transport modes have been facing the problem of emissions. Fossil fuels when burnt also generate emissions which are released to the atmosphere thereby altering the natural state of the atmosphere. Such emissions from industrial processes, forest fires, radiation etc. cause havoc to both the human health and the environment as they are emitted into the environment. Studies done to note the impact of anthropogenic pollution on the environment and human health has led to the regulatory body, World Health Organization (WHO) to implement emission reduction policies. On the global scale, studies have shown that fine and ultrafine aerosols fractions as well as their content in trace metals and organic compound, induce biological effects as a result of their ability to reach the distal lung" (Cassee et al., 2013). It equally highlighted and helped in the understanding of the size-speciation of the chemical composition of the main anthropogenic sources in various seasons

Studies showed that there is a relationship between high rate of mortality and fine aerosol concentration (Pope III, 2010). It has been reported that there was 1.5% increase in total daily mortality, deaths increase of 3.3% as a result of chronic pulmonary disease obstruction and deaths of 2.1% as a result of Ischemic heart disease for $PM_{2.5}$ increase of 10 $\mu g/m^3$ (Schwartz et al., 1996). Aerosol according to Literature has significant impacts on the health of humans as well as air quality, and visibility, radiative climate forcing, atmospheric heavy metal concentration. The understanding of the chemical characterization of urban aerosol is very crucial in the assessment of efficient control measures and management policy.

Aerosol particles in the atmosphere affect the quality of air and also affect the earth's meteorological cycle. Therefore, understanding their chemical characteristic is therefore needed. Hence, much work is still needed to enhance our understanding of the chemical composition, size distribution, source apportionment and indoor- outdoor relationship of urban aerosols in urban areas and their health impact upon exposure. (Lawal, 2015). Therefore, research should continue in this area for improvement of data and modes for air quality monitoring. Hence, the study attempts to assess the heavy metal concentration of aerosol around the residential and commercial areas of Port Harcourt metropolis. The main objectives of the study are to: Assess the daily variations in the heavy metal concentration of aerosol in residential and commercial areas of Port Harcourt metropolis.

2. Methodology

2.1. Method of Data Collection

The study assessed heavy metal concentration of aerosol in selected land Use types of Port Harcourt Metropolis. Residential density types and commercial area were used as the basis for data collection for the study. The sample frame for this study comprises residential land use type (which is made up of three residential density areas namely high density residential, moderate density residential and low-density residential areas) and also commercial land area in the city. Two sampling points were selected purposively from each high-density residential, low-density residential, moderate density residential areas and one sampling point from commercial area making a total of seven (7) stations sampled. Aerosol (TSP) samples were taken at the seven stations for seven consecutive days. The sampling points were selected such that major residential neighbourhoods and domestic fire and waste burning sites located in residential and commercial areas were covered (Mohr, 2011). Ezeh et al. (2012) observed that high volume sampling filters were exposed to the atmosphere for a period of 24 hours for the collection of particulate matter. The filter papers were exposed for a period of 24 hours to ensure size fractionation and collection efficiency. The exposed filter papers were thereafter preserved in the desiccators before taking them to the laboratory for analysis. The co-ordinates of the different stations sampled were also taken.

TSP (aerosol) sampling in the different sampling stations were taken for a period of seven consecutive days (Adon & Catherine, 2020) in each of the seasons (wet and dry) making it a total of 14 days of TSP (aerosol) sampling. The aerosol samples (49) collected in each of the seasons was hereafter subjected to environmental laboratory for 'bulk' laboratory analysis. The sum of 98 aerosol samples was collected in all from both wet and dry seasons. The heavy metal concentration of the aerosol was analysed for in each of the sampled aerosol (TSP). The aerosol sampling for this study covered the period of October - November 2021 reflecting the wet season and December–February, 2022 reflecting the dry season period. This covered 14 days (7 days in each of the two seasons). The choice of these seasons is based on rainfall distribution of Port Harcourt Metropolis. This is done to capture the possible potential fluctuations in the composition of aerosol in all the stations for all the seasons (Weli & Emenike, 2018). Accordingly, the co-ordinates of the different stations sampled (Table 1) were taken with the help of Global Positioning System (GPS) tool. This aids in the mapping of sample locations (Figure 1).

2.2. Procedure for Laboratory Analysis

An unexposed filter paper was kept as blank sample after 11cm diameter filter paper was exposed to atmospheric particulates. Afterwards, each filter paper was cut using a stainless-steel cutter and exactly 3% nitric acid and 8 % hydrochloric acid was added to the strips that were put in a 100ml Pyrex beaker. Sample was heated for 30 minutes. The digested samples were filtered into 100ml volumetric flask. The sample extracts were analysed using the GBC 90PBMT Atomic Absorption Spectrophotometer (ASS). The concentration of different test metals (Cu, Cr, Pb, Ni, and Fe) were obtained and expressed in ppm units.

Table 1: Sampling Stations and Coordinates

Residential Density Type	Station / Locations	Points	Latitudes (^{0}N)	Longitude (^{0}E)
High Density Residential	Diobu	HDR	4.79278	6.99242
			N^{0}47'38.888"	E6^{0}59'32.792"
	Ogbulabali		4.87291	6.99686
			N4^{0}52'224.332"	E6^{0}59'48.626"
Moderate Density Residential	D-Line	MDR	4.80425	7.00325
			N4^{0}48'15.276"	E7^{0}0'11.802"
	Atali		4.8789	7.05653
			N4^{0}52'44.064"	N7^0'3'22.998"
Low Density Residential	Old GRA	LDR	4.7825	7.00938
			N4^{0}46'57.012"	E7^{0}0'32.11"
	Rumuibekwe Estate		4.8402	7.05087
			N4^{0}50'24.738"	E7^{0}3'3.114"
Commercial Density Area	Mile 3 Market	CA	4.799	6.9921
			N4^{0}47`57.114''	E6^{0}59`31.884''

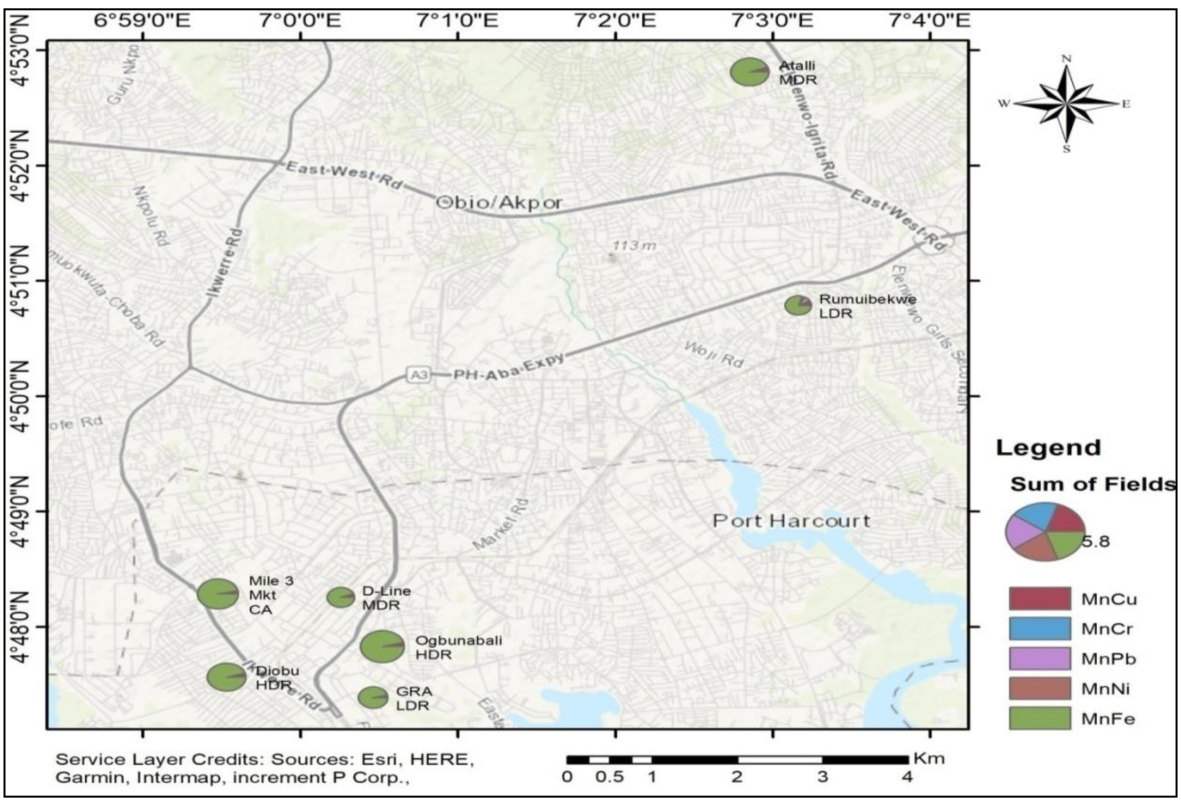

Figure 1: Map showing the Sampling Points for Aerosol Measurement in Residential and Commercial Areas of the study area.

3. Results

Table 2: Heavy Metal concentration of Aerosol across the Days of the Week (DO week).

Heavy Metals	Mean						
	Friday	Monday	Saturday	Sunday	Thursday	Tuesday	Wednesday
Cu(ppm)	0.068	0.061	0.07	0.092	0.034	0.062	0.075
Cr(ppm)	0	0	0	0	0	0.001	0.001
Pb(ppm)	0	0.004	0	0	0.006	0.064	0
Ni(ppm)	0.009	0.004	0.013	0	0.027	0.001	0.026
Fe(ppm)	1.127	1.015	1.504	1.135	1.416	1.616	1.356

3.1. Daily Variation in the heavy metal concentration of aerosol

The Mean daily variation in the heavy metal concentration of aerosol (selected heavy metals, Cu, Cr, Pb, Ni, and Fe) was examined amongst the different Days of the Week (DOW). Table 2 revealed that the values for the different heavy metal concentration of aerosol investigated vary across the different days of the week. Table 2 revealed that Fe (ppm) has the highest concentration value amongst the heavy metals investigated across the DOW having its highest concentration on Tuesday and lowest concentration on Monday. The heavy metal with the lowest concentration value amongst the heavy metal investigated across the DOW is Cr (ppm) having a negligible concentration values across the DOW. Cu has the highest mean concentration value on Sunday and has the lowest mean concentration value on Thursday. The heavy metals concentration of aerosol across the study area revealed that the concentration of Pb (ppm) across the different categories of the days of the week is the same except on Tuesday where its concentration is different and also highest. Ni (ppm) showed no variation in its mean concentration (values) in the different categories of the days of the week. Its highest mean concentration value occurred on Thursday (0.027) and its lowest mean concentration value occurred on Tuesday 0.001.

The concentration of Fe (ppm) as one of the heavy metal constituents of the aerosol studied across Port Harcourt Metropolis, the study area does not show a marked variation in the different days of the week. It has the highest mean concentration value on Tuesday (1.616) and the lowest on Monday (1.015).

Generally, the daily concentration of the heavy metals concentration of aerosol across Port Harcourt Metropolis, the study area showed that Fe (ppm) has the highest concentration followed by Ni (ppm) and then Pb (ppm) in the different days of the week (see Table 2) having their highest mean concentration values on different DO of the week.

3.2. Summary of ANOVA of Heavy Metals Concentration of Aerosol across the DO Week

Cu (ppm) across DO Week

Independent-Samples Kruskal Wallis Test Summary

Total N	98
Test Statistic	2.340
Degree of Freedom	6
Asymptotic Sig. (2-sided test)	0.886

For Cu (ppm) since the significant value 0.886 is greater than 0.05, the null hypothesis is retained. Therefore, the distribution of Cu (ppm) is the same across categories of DO Week. This means that there is no statistically significant daily variation in the concentration of the heavy metals, Cu across the DOW in the study area. Hence,

Table 3: ANOVA of Cu (ppm))

Null Hypothesis	Test	Sig	Decision
The distribution of Cu(ppm) is the same across categories of DO Week	Independent - Samples Kruskal Wallis Test	0.886	Retain the null hypothesis

Cr (ppm) across DO Week

Independent-Samples Kruskal Wallis Test Summary

Total N	98
Test Statistic	8.847
Degree of Freedom	6
Asymptotic Sig. (2-sided test)	0.182

The significance value of Cr (ppm) is 0.182 which is greater than 0.05, the null hypothesis is hereby retained. Therefore, the distribution of Cr (ppm) is the same across categories of DO Week. There are no statistically significant daily variations in the concentration of the heavy metals, Cr (ppm) across the DOW in the study area. Hence,

Table 4: ANOVA of Cr (ppm)

Null Hypothesis	Test	Sig	Decision
The distribution of Cr(ppm) is the same across categories of DO Week	Independent - Samples Kruskal Wallis Test	0.18 2	Retain the null hypothesis

Pb (ppm) across DO Week

Independent-Samples Kruskal Wallis Test Summary

Total N	98
Test Statistic	4.085
Degree of Freedom	6
Asymptotic Sig. (2-sided test)	0.665

For Pb (ppm) since the significant value 0.665 is greater than 0.05, the null hypothesis is retained. Therefore, the distribution of Pb (ppm) is the same across categories of DO Week. There is no statistically significant daily variation in the concentration of Pb across the study area. Hence,

Table 5: ANOVA of Pb (ppm)

Null Hypothesis	Test	Sig	Decision
The distribution of Pb(ppm) is the same across categories of DO Week	Independent - Samples Kruskal Wallis Test	0.665	Retain the null hypothesis

Ni (ppm) across DO Week

Independent-Samples Kruskal Wallis Test Summary

Total N	98
Test Statistic	9.059
Degree of Freedom	6
Asymptotic Sig. (2-sided test)	0.170

The significant value 0.170 is greater than 0.05, the null hypothesis is retained. Therefore, the distribution of Ni (ppm) is the same across categories of DO Week. There is no statistically significant daily variation in the concentration of Ni (ppm) across the study area. Hence,

Table 6: ANOVA of Ni (ppm)

Null Hypothesis	Test	Sig	Decision
The distribution of Ni (ppm) is the same across categories of DO Week	Independent - Samples Kruskal Wallis Test	0.170	Retain the null hypothesis

Fe (ppm) across DO Week

Independent-Samples Kruskal Wallis Test Summary

Total N	98
Test Statistic	3.236
Degree of Freedom	6
Asymptotic Sig. (2-sided test)	0.779

For Fe (ppm), its significant value 0.779 is greater than 0.05, the null hypothesis is retained. Therefore, the distribution of Fe (ppm) is the same across categories of DO Week. This means that there is no statistically significant daily variation in the concentration of the heavy metal, Fe across the study area. Thus;

Table 7: ANOVA of Fe (ppm)

Null Hypothesis	Test	Sig	Decision
The distribution of Fe (ppm) is the same across categories of DO Week	Independent - Samples Kruskal Wallis Test	0.779	Retain the null hypothesis

Conclusively, there is therefore, no statistically significant daily variation in the heavy metals concentration of aerosols in Port Harcourt Metropolis, Rivers State, Nigeria the study area. There is no statistically significant daily variation in the concentration of the heavy metals in TSP in the aerosol across the residential density areas and commercial area of Port Harcourt Metropolis, the study area.

4. Discussion

Daily variation in heavy metal concentration of aerosol

Table 2 revealed that Fe (ppm) has the highest daily concentration in aerosol across the days of the week in the study area having its highest concentration on Tuesday and lowest concentration on Monday. The high mean concentration value of Fe(ppm) may be connected to anthropogenic sources such as smelting activities. This aligns with the findings of Ukah et al., (2020) that anthropogenic activity of man results to the generation of toxic metals that have the capability of polluting the air thereby affecting the human health. On the other hand, Fe (ppm) as a heavy metal is an example of a crustal element; its high mean values could also be attributed to the unpaved nature of most Port Harcourt Metropolis roads and walkways. This finding is consistent with the findings of Ezeh et al., (2012) who found that the mean maximum of elemental concentration values for $PM_{2.5}$ fractions were observed for Copper, Iron, Calcium, Silica, Vanadium, Chlorine etc in Lagos State, their study area. The higher concentration of Fe (ppm) on Tuesday may equally be attributed to high rate of vehicular emissions due to the fact that many people board vehicles from neighbouring towns on Tuesday as against Oil Mile Market on Wednesday. Also, many people that travel over the weekend who could not come back on Monday as a result of Sit –At – Home of neighbouring states may likely come back on that Tuesday. This increases vehicular related traffic, leading to high level of vehicular emissions. High concentration of Iron on Tuesday is also related to anthropogenic activities like high fossil fuel burning for heating and cooking purposes, by people preparing for sales at Oil Mile Market on Wednesday. These anthropogenic activities add to TSP in the atmosphere. The high concentration of Fe (ppm) on Tuesday also typically indicates the contribution of crustal mineral on that Tuesday, (Kumar & Sarin, 2020).

5. Conclusion

The study revealed the heavy metal concentration of aerosol in the Total Suspended Particulate in Port Harcourt Metropolis of Rivers State, Nigeria. The study of urban air monitoring of Particulate Matter has produced a new set of more robust data of heavy metals in Total Suspended Particulate concentrations in Port Harcourt Metropolis, Rivers State, Nigeria. The study revealed that Iron was prevalent in the Land Use Area (Residential Density and Commercial Areas). The findings from the study are useful in the estimation of concentration of other heavy metals in the particulate matter across other locations in the same area of study. The study therefore concludes that these metals (Cu, Cr, Ni, Pb, Fe etc) which are suspended in the atmosphere can be toxic to humans at continuous exposure even at very low concentration.

References

Abbas, S. A. (2009). Air pollution, particulate matter (PM2.5)-induced gene expression of volatile organic compound and/or polycyclic aromatic hydrocarbon-metabolizing enzymes in an in- vitro coculture lung model. *Toxicology In-Vitro*, 23, 37-46.

Adon, A. J. & Catherine, L. (2020). Physico-chemical characterization of urban aerosols. *Atmospheric Chemistry and Physics*, 5327-5354. www.atmos-chem-phys.net/20/5327.

Cassee, F. R., Héroux, M. E., Gerlofs-Nijland, M. E. & Kelly, F. J. (2013). Particulate matter beyond mass: recent health evidence on the role of fractions, chemical constituents and sources of emission. *Inhalation Toxicology*, 25, 802-812.

Ezeh, G. C., Imoh B. O., Olabode I. A., & Olawale E. A. (2012). PIXE characterization of PM_{10} and $PM_{2.5}$ particulates sizes collected in Ikoyi Lagos, Nigeria. *Toxicological & Environmental Chemistry*, 94(5), 884-894. DOI: 10.1080/02772248.2012.674133

Kim, K. H., Kabir, E., & Kabir, S. (2015). A review on the human health impact of airborne particulate matter. *Environment International*, 74, 136-143.

Kumar, A., & Sarin, K. (2020). Geochemical characterization of modern aeolian dust over the northeastern Arabian Sea: Implication for dust transport in the Arabian sea. *Science of the Total Environment*, 729, 138576. doi:10.1016/j.scitotenv.138576

Lawal, O., & Asimiea, A. (2015). Spatial Modeling of Population at Risk and $PM_{2.5}$ Exposure Index. A case study in Nigeria. *Ethiopian Journal of Environmental Studies & Management*, 8(1), 69-80.

Maier, K. L., Alessandrini, F., & Beck-Speier, I. (2000). Health effects of ambient particulate matter– biological mechanisms and inflammatory responses to in-vitro and in-vivo particle exposures. *Inhalation Toxicology*, 20, 319-337.

Mohr, C. (2011). Spatial variation of chemical composition and sources of submicron aerosol in Zurich during wintertime using mobile aerosol mass spectrometer data. *Atmospheric Chemistry and Physics, 11, 7465-7482.*

Pope III, C. A. (2010). Review: Epidemiological basis for particulate air pollution health standards. *Aerosol Science and Technology*, 32(1), 4-14.

Putaul, J. P. (2010). An European aerosol phenomenology-3: Physical and chemical characteristics of particulate matter from 60 rural, urban, and kerbside sites across Europe. *Atmospheric Environment, 44(10), 1308-1320.*

Ravindra, K., Sokhi, R., & Van Grieken, R. (2008). Atmospheric polycyclic aromatic hydrocarbons: Source attribution, emission factors and regulation. *Atmospheric Environment (*42) 2895-2921.

Romieu, I., Gouveia, N., Cifuentes, L.A., de Leon, A.P., Junger, W., Vera, J. & Tzintzun-Cervantes, G. (2012). Multicity study of air pollution and mortality in Latin America (the ESCALA study). *Respiratory Research: Health Effects Institute*, (171) 5-86.

Schwartz, J., Ballester, F., Saez, M., Pèrez-Hoyos, S., Pèrez-Boillos, M. J., & Sunyer, J. (1996). The concentration-response relation between air pollution and daily deaths. *Environmental Health Perspectives*, 109, 1001-1005.

Shi, Y., Ji, Y., & Sun, H. (2015.). Nanoscale characterization of $PM_{2.5}$ airborne pollutants reveals high adhesiveness and aggregation capability of soot particles. *Scientific Reports*, 5(3), 181-183.

Ukah, B. U., Ameh, P. D., Egber, J. C., Unigwe, C. O., & Ubido, O.E. (2020). Impact of effluent derived heavy metals on the groundwater quality in Ajao Industrial area, Nigeria: an assessment using entropy water quality index (EWQI). *International Journal of Energy and Water Resources*, 10(20), 120-138.

Weli, V. E., & Emenike, G. C. (2018). Atmospheric Aerosol Loading over the Urban Canopy of Port Harcourt City, Nigeria. *International Journal of Environment and Pollution Research*, 6(2), 38-53.

Zhang, X., Wang, Y., Niu, T. (2012). Atmospheric aerosol compositions in China: Spatial/temporal variability, chemical signature, regional haze distribution and comparisons with global aerosols. *Atmospheric Heavy metals concentration and Physics*, (12), 779-799.