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Geo-Mapping of Trace Metal Concentrations in Respirable Particulate Matter in South-South, Nigeria

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Abstract— *Globally, atmospheric pollution is one of the most significant and potentially catastrophic environmental issues threatening the world particularly with climate change on the horizon. In this study, the geo-mapping of trace metal concentrations present in respirable particulate matter in Ibeno local government area of Akwa Ibom state, south-south, Nigeria was attempted. Analysis of trace metals Cr, Zn, Ni, Mn, Fe and Pb in Ibeno was done using atomic absorption spectroscopy (AAS) closely followed by the geo-mapping and spatial analysis of the respective trace metals during wet and dry season The mean concentration of trace metals in respirable particulate matter were 0.3038 ppm, 0.0482 ppm, 0.0187 ppm, 0.0156 ppm, 0.0032 ppm and 0.001 ppm for Mn, Zn, Fe, Pb, Ni and Cr respectively for the dry season, while the wet season was 0.2212 ppm, 0.1595 ppm, 0.0172 ppm, 0.0343 ppm, 0.0040 ppm and 0.002 ppm for Fe, Mn, Pb, Zn and Ni in that order. The spatial distribution in dry season showed hot spots (high concentration) with large location coverage for Zn and Fe compared to Cr, Pb, and Ni. Higher concentration of trace metals (Cr, Pb, Ni) were observed around vast areas of the sample locations in the wet season but was not the case for Fe and Zn while Mn had a different pattern in both seasons.*

Keywords— *Geographical information system (GIS), respirable particulate matter, air pollution, spatial analysis, trace metals.*

I. INTRODUCTION

Atmospheric pollution is one of the most significant and potentially catastrophic environmental issues threatening the world today. And it is the presence of certain substances in the atmosphere at certain levels and duration that produce harmful effects on man and his environment (Rana, 2013). The amount of pollutants in the air is expressed in terms of its mass/volume concentration, usually as micrograms of pollutant per cubic metre of air ($\mu g/m^3$). The concentration of pollutants varies widely depending on the sources of pollution, their distribution, meteorological conditions and the topographical features in the vicinity. Common air pollutants include carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), trace metals (Pb), respiratory suspended particulate matter (RSPM) and total suspended particulates (TSP) which include dust, smoke, pollen and other solid particles (Kariuki, 2001).

Atmospheric deposition of toxic trace metals has stimulated profound research all over the world due to the extent of their harmful effects on living organisms (Shrivastav, 2001). Toxic metals like lead (Pb), cadmium (Cd), arsenic (As) and chromium (Cr) can essentially attack specific areas in the human body upon exposure (Shinggu et al., 2007). Their dispersion and transport in the atmospheric layers may be exacerbated by human activities and natural phenomena. The resulting high concentrations of these metals in the air may lead to both ecotoxic effects on plants and animal species, and genotoxic effects on humans (Matejicek 2005 and Xiao-li et al., 2006). Rapid urbanisation and increase in the number of motor vehicles on roadways have heightened concentrations of trace metals in the air above levels at which they naturally occur (Xiao-li et al., 2006). Evidently, some of these metals are essential for life at very low concentration levels but at high levels may lead to harmful effects in humans, plants and animals. Those that are of grave concern are the non- essential toxic trace metals like As, Pb, Cd and Cr which may be considered major air and land pollutants in areas where they are most concentrated (Moses et al., 2009).

GIS has become a useful tool in air pollution study. It helps in a comprehensive manner to understand the scenario of air pollution in city by generating a thematic map. In this way it is evident from the literature that proper management strategies can be taken with the help of this database management system. Afshar and Delavar 2007 did a GIS-based air pollution modelling in Tehran. In that research a prediction model was developed for air pollution in 2004 using the data of 2002 and 2003. Additionally by using the method of local contribution to concentration in canyon streets, the concentration of both CO and NO_2 at each month and for six highways of Tehran and for each vehicle was calculated. The prediction model was a GIS-based model that had taken geometry of the streets and vehicle numbers. A series of extensions was built by Matejicek 2005 into the GIS to adapt its functionality. As examples, the spatial models of a flat urban area and a street canyon with extensive traffic polluted with NO_x were constructed and influential sources of pollution evaluated. Weng and Yang 2006 investigated the relationship of local air pollution pattern with urban land use and with urban thermal landscape using a GIS approach for Guangzhou City in South China between 1981 and 2000. Results showed that the spatial patterns of air pollutants probed were positively correlated with urban built-up density and with satellite derived land surface temperature values, particularly with measurements taken during the summer. It was also inferred from the result that two urban cities (Liwan and Yuanchun) were the pollution hubs of SO_2, dust and other pollutants, and this was probably due to locations of industrial plants, high population density, clustering of catering industry and low air flushing rates.

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II. Material and Methods

Study Area and Sampling

Ibeno Local Government Area is located at the South end of Akwa Ibom State and occupies the largest coastline (Fig. 1) with general coordinates between 4°32'02"N, 4°36'02"N.36 and 7.48"E, 8°17'42"E, and based on data from 2006 Nigeria's national census, it is home to 74,840 people (NPC, 2006). Ibeno is host for oil producing and several oil servicing companies which are dynamic and attracts complimentary economic activities such as sand blasting, spray painting, carpentry and welding works, water and land transportation, fishing, production and sales of fishing nets, construction of boats and canoes.

Respirable suspended particulate matter was collected from nine sampling sites using SKC respirable dust sampler (model 224-PCXR8) following the standard procedures. Pre-weighed Whatman No.41 filter papers were used. After sampling, the filters were changed and individually placed into pre-cleaned aluminum foils for transportation and subsequent analysis. Reweighing of the filter paper (using ultra-microbalance) immediately after direct sampling under carefully controlled conditions gave a direct measurement of the level (RSPM).

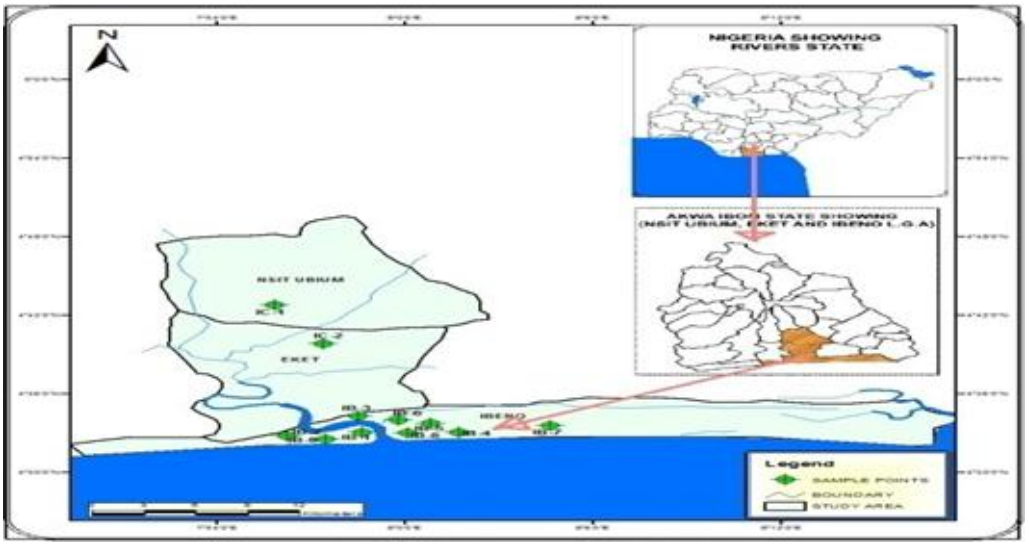

Fig. 1: Map showing sample points

Digestion Procedure for Filters

The exposed Whatman filters were cut into pieces by means of clean stainless steel scissors and transferred into a 250 ml beaker. To the beaker, 6 ml of concentrated nitric acid, 4 ml of hydrogen peroxide (30 %) and 50 ml of distilled water were added, and then covered with a watch glass. This was heated on a hot plate until most of the acid evaporated. Same procedure was repeated at least twice. This was replicated until the residue was barely dry and a white ash appeared. The residue was dissolved in 5 ml of concentrated nitric acid. The digest was filtered, with thorough washings of nitric acid into a 25 ml volumetric flask and made up to mark with dilute nitric acid. A blank unexposed filter paper was similarly digested for blank correction.

Determination of Trace Metal Concentration

The concentration of trace metals were determined using atomic absorption spectrophotometer (AAS; SOLAAR 939, ATI UNICAM) equipped with flame furnace. The digested samples (digests) were directly introduced into the flame with continuous aspiration through the polythene tubing and the concentration of the element was obtained from the calibration plot. The concentration of trace metals in the extracts were determined by comparing the absorbance of the standard metal solution. The concentrations of trace metals were expressed in ppm. All analyses were carried out in duplicate and for each run. Two blanks and a reference sample were analysed using the same procedure in order to ensure precision and accuracy of the analytical methods. The mass concentration of trace metal (e.g lead) was expressed in parts per million in air sample and were estimated to the nearest 0.1 µg/m^6 using equation 1

$$Pb\ (conc) = [Pb(sm) - Pb(bl)] \times {}^{V_1}/_{V} \quad (1)$$

where Pb (conc) = mass concentration of particulate lead in µg/ml

Pb (sm) = concentration of particulate lead, in µg/ml in sample solution

Pb (bl) = concentration of particulate lead, in µg/ml in blank solution

V_1= total volume of digested sample in ml and

V = volume of air sampled in m^6.

The concentrations of Fe, Zn, Mn, Cr and Ni were analysed and calculated according to eqn (1).

The GIS mapping was done using ARCMAP 9, software that allows viewing of spatial data, creation of layered maps, and perform basic spatial analysis.

III. Results and Discussion

Trace Metals in Respirable Suspended Particulate Matter

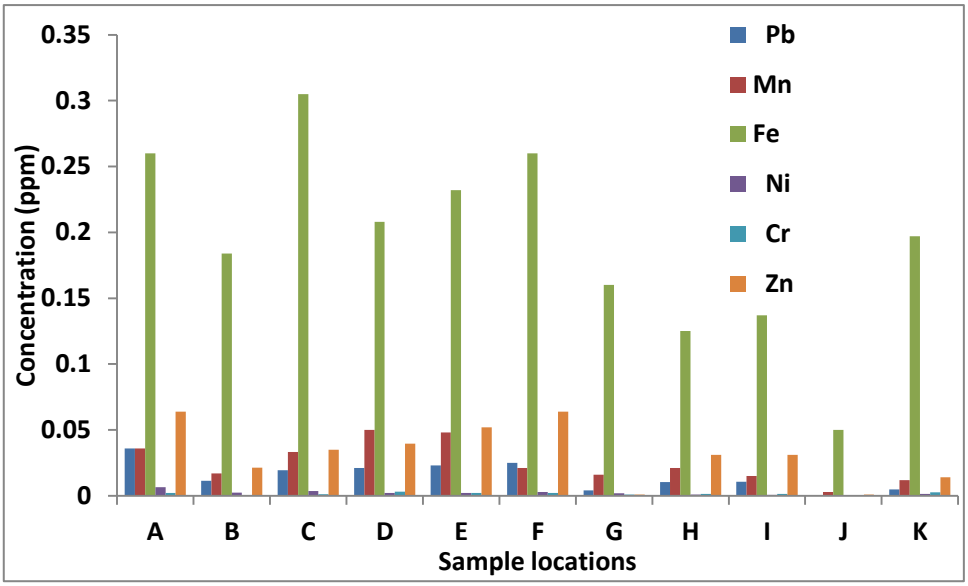

Fig. 1: Monthly trace metal concentrations in Ibeno (A) Nov (B) Dec (C) Jan (D) Feb (E) Mar (F)Apr (G) May (H) Jun (I) Jul (J) Aug (K) Sept

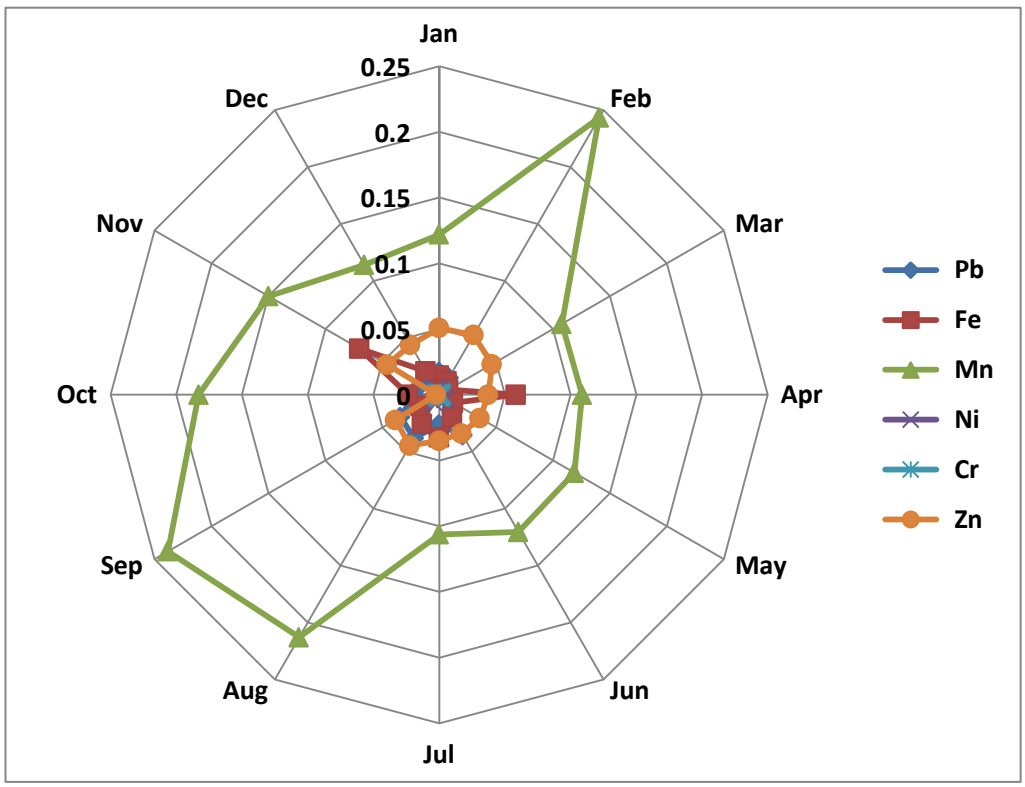

Fig. 2: Average monthly concentration of trace metals in respirable suspended particulate matter in Ibeno

The concentration of Fe is highest throughout the year especially in the month of (D) February The geogenic nature of Fe in this location could be a factor and also considering that February is dry and windy making it relatively easy for RSPM to be dispersed (Melaku *et al.* 2008). Zinc concentration was also consistently high while Lead (Pb) concentrations showed high monthly variability range with the lowest of these concentrations in two months (March and April, 2019), probably due to the washout by rains, while the highest was in the month of August, 2019. The increase in the

month of August, 2019 may be due to increase in vehicular traffic and the road construction work during the period. These concentrations however were comparable with the value for wet deposition in the work by Melaku *et al.* 2008, but differed from the report of Theodosi *et al.* 2010.

The lowest average monthly concentrations of lead were during March and April, 2019 with concentration values of 0.0087±0.02 ppm. The highest average monthly concentration was in the month of August 2019 (0.382±0.02 ppm). This was closely followed by 0.0358±0.01 in the month of June, 2019.

The range of average monthly concentration of Fe was from 0.0081±0.01ppm to 0.0701±0.12 ppm in the months of March 2019 and November 2019 respectively. The average monthly concentration of Mn was 0.1062±0.01 ppm to 0.8434±0.47 ppm in the month of July 2019 and February 2019 respectively. The lower limit was within the federal environmental protection agency (FEPA) and National Ambient Air Quality Standards (NAAQS) limits of 0.15 ppm, while the upper limit exceeded.

The average monthly concentration range of Cd was from 0.0006±BDL to 0.0157±0.008 ppm in the months of May and September, 2019 while average monthly concentration range of Ni was from <0.0001 (which is below detection limit) to 0.0071±0.001 ppm in the months of April and August, 2019.

That of March, 2019 was lowest probably due to washouts by the early rains and highest in November, 2018 most likely due to increased farming activities during this period and changes in the weather. There was however a fall in the concentration in the month of December, 2018 to March, 2019 probably due to a combination of wind action and washout by rains. Thereafter, the concentration increased in April, 2019 despite the rains due to increased combustion processes around the study area at those times. This result was lower than the results of Uno *et al.* 2013, Kim *et al.,* 2002 and similar to that of Mufuyai, et al., 201.

Manganese had undulating monthly variations during the period of this study. The first three months of sampling had low concentration levels possibly due to wind actions (Hung *et al.,* 2005), then an increase to a peak in February, 2019 attributed to road construction work at Eket-Ibeno road from where Mn could have been re-suspended (Mufuyai et al., 2014) coupled with increased farming activities. Thereafter, the rise and fall pattern in concentration occurred till the last month of sampling. This was ascribed to changes in weather pattern and wind actions (Hung *et al.,* 2005) and this result was higher than that reported by Mufuyai *et al.* 2014.

There was decrease in average concentration of Cd in the dry months probably due to increased wind speed which does not support pollutant accumulation (Tsai *et al.,* 2004; Hung *et al.,* 2005). Road construction and the community building projects could have also contributed to high Cd. The lowest average concentration of Cd was during the wet months and could have been as a result of the heavy and frequent rains prevalent in those months. This was similar to the report of Ediagbonya *et al.* 2013 but different from the result of Ekpo *et al.* 2012.

The concentration of chromium also had some variations with the lowest in the dry months probably due to meteorological influences (Garcia *et al.,* 2007), while the highest average concentration was in the wet months probably due to incineration of biomass and waste, metal welding works and road projects (Hlavay *et al.,* 1998). This result was similar to the report of Ediagbonya *et al.* 2013 but different from the result of Ekpo *et al.* 2012.

Zinc had an undulating trend in the variability of its monthly average concentration. There was increase in the dry months due to higher trace metal depositions by downward wind actions (Garcia *et al.,* 2007), while the remaining months of sampling showed a comparative decrease in concentration. The average monthly concentration of Zn was lower than that obtained by Ediagbonya *et al.* 2013.

TABLE 1: Average concentration of trace metals in respirable suspended particulate matter in dry season in Ibeno

Trace metals	Average concentration (ppm) in sample points										
	1	2	3	4	5	6	7	8	9	10	11
Pb	0.0263 ±0.03	0.0115 ±0.04	0.0129 ±0.10	0.0171 ±0.08	0.0205 ±0.02	0.0228 ±0.01	0.0051 ±0.07	0.0116 ±0.13	0.0127 ±0.05	0.0005 ±0.03	0.0048 ±0.05
Fe	0.0262 ±0.09	0.0175 ±0.06	0.0150 ±0.03	0.0209 ±0.04	0.1056 ±1.44	0.0204 ±0.06	0.0129 ±0.03	0.0157 ±0.05	0.0290 ±0.07	0.0042 ±0.04	0.0076 ±0.05
Mn	0.2319 ±0.46	0.1819 ±0.14	0.4938 ±0.31	0.2723 ±0.39	0.3611 ±4.30	0.4315 ±1.27	0.2918 ±5.97	0.1985 ±1.61	0.2714 ±0.16	0.1454 ±1.04	0.1359 ±1.08
Ni	0.0086 ±0.25	0.0049 ±0.19	0.0050 ±0.57	0.0045 ±0.52	0.0023 ±0.81	0.0013 ±1.75	0.0013 ±0.72	0.0006 ±1.03	0.0007 ±1.21	0.0001 ±0.59	0.0012 ±0.47
Cr	0.0011 ±3.26	0.0002 ±0.14	0.0006 ±0.41	0.0025 ±0.32	0.0012 ±0.91	0.0010 ±0.19	0.0002 ±0.95	0.0009 ±0.16	0.0013 ±0.29	0.0001 ±0.13	0.0008 ±0.68
Zn	0.0751 ±0.16	0.0244 ±0.07	0.0405 ±0.25	0.0413 ±0.25	0.0608 ±0.16	0.0510 ±0.20	0.0696 ±0.02	0.0356± 0.27	0.0363 ±0.20	0.0008 ±0.12	0.0025 ±0.10

1 = IB-1 (Iwuoachang), 2= IB-2 (Okoroutip), 3 = IB-3 (Ukpenekang), 4 = IB-4 (Esit Eket Road/Frontier Oil), 5 = IB-5 (Terminal Road, Mkpanak), 6 = IB-6 (Douglass Street), 7 = IB-7 (Ine Anwa), 8 = IB-8 (Inua Eyet Iko), 9 = IB-9 (Iwuo-Okpom), 10 = IC-1 (Ikot Ontong) and 11 = IC-2 (Ikot Usoh Ekong)

The average concentration of Pb in the dry season was between 0.0115±0.04 to 0.0263±0.03 ppm at sites IB-2 and IB-1 respectively. The trend of concentrations in the different sampling sites were in the order IB-1>IB-6>IB-5>IB-4>IB-7>IB-3>IB-9>IB-8>IB-2.

The average concentration of Fe during the dry season ranged from 0.0129±0.03 ppm to 0.1056±1.44 ppm at locations IB-7 and IB-5 respectively but followed the order IB-5>IB-9>IB-1>IB-4>IB-6>IB-2>IB-8>IB-3>IB-7.

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As regards Mn in the dry season, the average concentration range was from 0.1819±0.14 ppm to 0.4938±0.31 ppm at sites IB-2 and IB-3 respectively. The descending order of concentration in the sampling sites was IB-3>IB-6>IB-5>IB-7>IB-4>IB-9>IB-1>IB-8>IB-2.

Average concentration for Cd during the dry season ranged from 0.0063±2.62 ppm to 0.1427±2.95 ppm at sites IB-7 and IB-9 respectively while the general trend through the sited are IB-9>IB-1>IB-3>IB-6>IB-2>IB-5>IB-4>IB-8>IB-7.

The average concentration for Cr at the dry season in Ibeno was 0.0002±0.14 ppm to 0.0025±0.32 ppm at sites IB-2 and IB-4 respectively. The trend in concentration in descending order was IB-4>IB-5>IB-9>A>IB-6>IB-8>IB-3>IB-2=IB-9.

TABLE 2: Average concentration of trace metals in respirable suspended particulate matter in wet season in Ibeno

Trace metals	Average concentration (ppm) in sample points										
	1	2	3	4	5	6	7	8	9	10	11
Pb	0.0408 ±0.09	0.0112 ±0.08	0.0226 ±0.21	0.0066 ±0.23	0.0243 ±0.21	0.0260 ±0.22	0.004 ±0.07	0.0099 ±0.20	0.0097 ±0.05	0.0003 ±0.001	0.0088 ±0.001
Fe	0.041 ±0.27	0.0160 ±0.25	0.0139 ±0.26	0.0659 ±0.25	0.0169 ±0.24	0.0196 ±0.24	0.017 ±0.23	0.0238 ±0.21	0.0073 ±0.21	0.0023 ±0.03	0.0136 ±0.001
Mn	0.2748 ±1.67	0.1850 ±0.63	0.2105 ±1.97	0.1759 ±1.02	0.1670 ±2.17	0.1590 ±3.01	0.0944 ±1.90	0.0881 ±1.57	0.0812 ±1.25	0.0034 ±0.15	0.0078 ±0.34
Ni	0.0062 ±0.07	0.0032 ±0.07	0.0057 ±0.07	0.0026 ±0.07	0.0038 ±0.06	0.005 ±0.07	0.0049 ±0.06	0.0031 ±0.06	0.0018 ±0.07	0.0002 ±0.03	0.0016 ±0.02
Cr	0.0026 ±0.04	0.0006 ±0.03	0.0015 ±0.02	0.0034 ±0.02	0.0025 ±0.03	0.003 ±0.04	0.0012 ±0.01	0.0017 ±0.02	0.0018 ±0.02	0.0002 ±0.01	0.0021 ±0.01
Zn	0.0541 ±0.67	0.0182 ±0.04	0.0296 ±0.05	0.035 ±0.16	0.0450 ±0.17	0.0638 ±0.03	0.0112 ±0.56	0.0257 ±0.07	0.0258 ±0.56	0.0006 ±0.01	0.0192 ±0.03

During the wet season the average concentration range for Pb was 0.004±0.07 ppm to 0.0408±0.09 ppm at locations IB-7 and IB-1 respectively. The trend was IB-1>IB-6>IB-5>IB-3>IB-2>IB-8>IB-9>IB-4>IB-7 while that of Fe was IB-4>IB-1>IB-8>IB-6>IB-7>IB-2>IB-3>IB-5>IB-9 with average range between 0.0073±0.21 and 0.0659±0.25 ppm at sites IB-9 and IB-4 correspondingly. In the case of Mn, it spanned from 0.0812±1.25 ppm to 0.2748±1.67 ppm at site IB-9 and IB-1. Though, the trend in concentration was IB-1>IB-3>IB-2>IB-4>IB-5>IB-6>IB-7>IB-8 IB-9.

Similarly, that of Cd was between 0.0039±0.10 ppm and 0.0140±0.023 ppm at sites IB-9 and IB-1 respectively with distribution as follows; IB-1>IB-4>IB-5>IB-3>IB-6>IB-7>IB-2>IB-8>IB-9. Chromium concentration in the wet season also spanned from 0.0006±0.03 ppm to 0.0034±0.02 ppm at sites IB-2 and IB-4 respectively. The trend in concentration in descending order was IB-4>IB-6>IB-1>IB-5>IB-9>IB-8>IB-3>IB-7=IB-2

There were variations in trace metals concentration from one site to another and the lowest average concentration of lead on site-to-site basis was at a non-residential site (IB-7) with low traffic density, low commercial activity and along the sea shores. Hence, sea breeze may have been a likely factor for the low concentration (Habeebullah, 2019). The highest Pb concentration at IB-1 was attributed to the synergistic effects of commercial, vehicular traffic as well as the presence of dump site on this sampling site. This result was similar to reports by Kanellopoulou, 2001 and Ite *et al.* 2014.

Iron had the lowest average concentration at IB-4 monitoring site, perhaps because this was a non-industrial and low residential site with medium traffic/commercial activities, while the highest average concentration was at D and majorly due to the industrial activities as well as high vehicular emissions. This was similar to the results of Lee and Nguyen 2011 and Kuvarega and Taru 2008.

The lowest average concentration of manganese was in location H probably because it was a medium traffic density and low residential area; hence its limit was within the FEPA limit of 0.15 ppm. The highest average concentration was at location C, probably because it was a high commercial and high traffic area hence above NAAQS standard. The result range in this work was different from that of Manoli, et al., 2002 and Mahmud, et al., 2008.

The lowest average concentration of Cd was at location G, which although close to the gas flaring stack was enclosed by the Qua Iboe River hence the possibility of sea breeze effect bringing dilution effect to the pollutant, coupled with the low vehicular movement around this location. The high concentration sites were the high traffic and high commercial area hence strong vehicular contribution suggested. This result differed with that in the works of Salem *et al.,* 2008 and Zereini *et al.,* 2005.

Ni generally had the lowest concentration of trace metals under consideration in the study area. This could be because it usually occurs at very low levels in the environment. The lowest average concentration however was at IB-9 probably because of its non-industrial and medium vehicular traffic activities. The highest concentration of Ni was at IB-1 which may be due to its high vehicular movement which could cause re-suspension of soil particles with Ni thus increasing its concentration (Hitchins, et al., 2000; Conko, et al., 2004) and from combustion of fuel and residual oil burning (ATSDR, 2005). High commercial activities could also have been a contributing factor. This was lower than the results of Tawari and Abowei 2012.

The highest concentration of Zn was at the high traffic area of A indicative of traffic emission and fish smoking activities as a contributing factor, while the lowest was at G, while the lower concentration may be due to the effect of sea breeze which could blow off and disperse the pollutants despite its closeness to the flaring site at IB-6. This result was different

from the results of Ocak and Turalioglu 2008; Leilli *et al.* 2008 but similar to the result of Abbasi and Tufail 2013.

There were lots of seasonal variations on the concentration of trace metals. The average concentration of lead was higher during the wet season than in the dry season despite higher wind speed range during the dry season. This may have been due to downwind direction which is said to give comparatively high concentration of pollutants on downwind sites than upwind direction (Garcia *et al*, 2007; Hung *et al*, 2005; Tsai *et al*, 2004). The concentration ranges in both seasons were lower than the concentrations reported by Obioh et al., 1988 but within the WHO and FEPA standards of 0.05ppm each. The average lead concentration being lower in the dry season than wet season was contrary to the findings of Ewa *et al*, 2013; Uno *et al.*, 2013; Melaku *et al*., 2008; Olobaniyi and Efe 2007 but was in agreement with the work of Ekpo *et al.* 2012 where the mean levels of trace metal were higher during the wet season than the dry season. Since the average concentration ranges in both seasons were within required standard limits, the inhabitants of Ibeno local government area are less prone to lead poisoning, but measures should be taken to ensure that it does not go beyond the set limit.

Iron had the average concentration range which was higher during the wet season than dry season. The highest concentration areas during wet season coincided with the industrial areas of D, while that for the dry season was at the high traffic density of 1B- 1. This indicated that industrial activities and traffic emissions greatly contributed to their high concentration. Besides, particles from ongoing traffic could have been re-suspended in the air (Sabin, Lim, Stolzenbach and Schiff, 2006). The lowest concentration was at residential areas of G for dry season and I for the wet season.

This trend of result was similar to the report of Ewa *et al.*, 2013 and Ekpo *et al.*, 2012 where the levels of Fe were also lower during the dry than the wet season and within the FEPA and WHO standards, but lower than the concentration obtained by Uno *et al.*, 2013, while Salem *et al.* 2008 had result with higher concentrations than FEPA's.

During the dry season, Mn concentration was highest at the 1B-3 location and this was likely due to high commercial activities, medium traffic density and emissions from gas stations within this location. This was closely followed by that at 1B-6 and this may likely have been due to industrial emissions as well as high traffic density. The lowest concentration during the dry season was at 1B-2 despite the medium traffic density and commercial activities, this implied that other factors like wind speed and direction might have come into play in dispersing the pollutant (Ocak and Turalioglu, 2008).

Manganese generally had lower average concentration of trace metal during the wet season than during the dry. The percentage increase during the dry season was 52.50%. This was in agreement with the works of Chattopadhyay 2014 and Dubey *et al.*, 2012 where the concentrations of Fe in dry season were higher than in the wet season, but dissimilar in trend of higher average concentration during the wet season than during dry season in the result of Ewa *et al.*, 2013.

The average concentration of Cd during the dry season was highest at the I which is a medium traffic area. This could have been due to increasing transportation activities resulting from the commercial activities of fish smoking and sales predominant in the area. Fishing and ferry transportation businesses at the jetty may also have contributed to Cd increasing concentration in the location. This concentration was higher than the regulated 0.05 ppm for NAAQS, WHO and FEPA standards. The average concentration for cadmium during the wet season was found to be lower than that reported for wet season by Okuo and Okolo 2011.

The average concentration of Cd for dry season was higher than for the wet season. The concentrations for Cd decreased from the dry to the wet season by 31.16%. The high-low seasonal concentration trends observed for the wet and dry seasons suggested the influence of meteorological conditions on local and regional sources. The highest seasonal concentration level in this study was considerably lower than the maximum seasonal Cd concentration found by Melaku *et al.*, 2008 in Washington, DC, but was similar to the results of Ediagbonya *et al.*, 2013 and Mufuyai *et al.*, 2014. It however differed from the findings of Leilli *et al.* (2008) with much higher concentration during wet season. Wu *et al.* 2008 had a significantly higher concentration during the wet winter season than the dry post monsoon season, while Weiwei *et al.*, 2006 had a higher concentration of Cd than that in this study. Having an elevated Cd concentration higher than the required standard has health and environmental implications especially damage to the liver, kidney and bones (Csuros and Csuros 2002 and Tillet, 2010).

Generally, Ni had the higher average contribution at the dry season than the wet season, and this could be attributed to the low influx of fresh water and higher evaporation rate with consequent concentration of pollutant in the site (Nwadinigue *et al.*, 2014). Result obtained in this study was lower than that by Mufuyai *et al.*, 2014 and Nwadinigwe *et al.*, 2014 but similar with the result of Fomba et al., 2013; Faridul, et al., 2019 and Bennett, 1994. Smith *et al.*, 1996 and Emoyan *et al.*, 2006, however had higher concentration values than this study.

The average concentration of Cr during the wet season was higher than during the dry season. There were however similarities with the peak concentrations in both seasons with the peak in each being at location D (this could have been due to the gas flaring from the different flare stacks at this site and traffic activities). The lowest concentration also coincided at positions B. A sharp decline of 50% was observed in the concentration of chromium from the wet season to the dry season which differed with the observations of Melaku *et al.* 2008 with 38.46% increase from wet to dry season. All the monitoring sites had concentrations higher than the WHO value of 0.05 ppm and FEPA standard of 0.06 ppm. These result were lower than the results of Garrison *et al.*, 2010; Kim *et al.* 2002; Shaheen *et al.*, 2005 and Goforth and Christoforai 2006, while the average concentration range of chromium in the wet season was similar with the level of chromium in the work done by Emoyan *et al.* 2006.

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For zinc, the highest average concentration was observed to be higher during the dry season than during the wet season. The highest average concentration of trace metal during the dry season was comparable to the work of Ediagbonya *et al.*, 2013, while that for the wet season was lower than the work of Ewa *et al.*, 2013.

Geographical Information System

The result of the geographical information system mapping for the average concentration of trace metals, respirable suspended particulate matter and atmospheric oxides for Ibeno during the study period were as presented in figures.

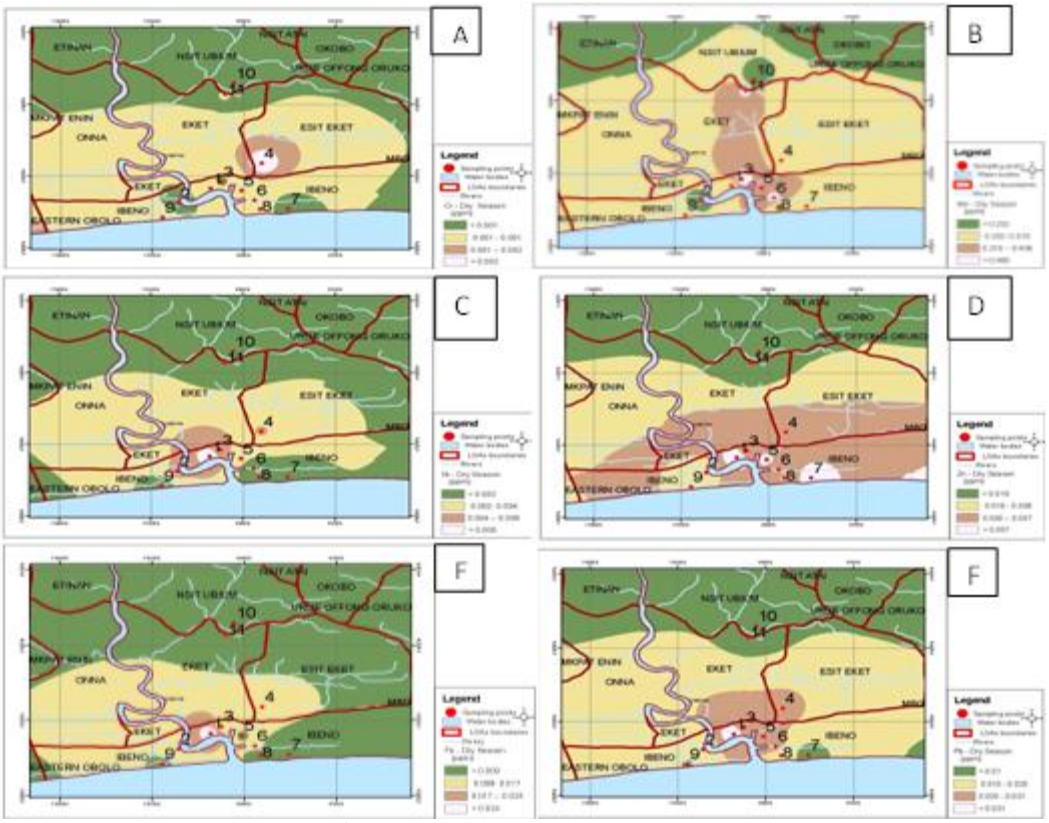

Fig. 3: Spatial interpolation of (A) Cr (B) Mn (C) Ni (D) Zn (E) Fe and (F) Pb in dry season at Ibeno

1 = IB-1 (Iwuoachang), 2= IB-2 (Okoroutip), 3 = IB-3 (Ukpenekang), 4 = IB-4 (Esit Eket Road/Frontier Oil), 5 = IB-5 (Terminal Road, Mkpanak), 6 = IB-6 (which is Douglass Street),7 = IB-7 (Ine Anwa), 8 = IB-8 (Inua Eyet Iko), 10 = IC-1 (Ikot Ontong) and 11 = IC-2 (Ikot Usoh Ekong)

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The scenario of the spatial distribution of chromium had the hot spot (that is very high concentration) during both the wet and the dry seasons centered at the around the industrial area of 1B-4 location with a slightly large spread at the wet season. The moderately high concentration portion of the Cr spread more widely and centrally in the study area at the wet season and spread to cover other locations such as 1B-3, 1B-5, 1B-6, and 1B-8, while the dry season spread only around the immediate vicinity of the 1B-4 location. The very low concentration portion of Mn spread wider at the dry season covering the North-North (NN), North-East (NE), North-West (NW), North Central (NC) and patches around the south-south (SS) part of the study area. This may have been due to change in wind direction and increase in the wind speed at the dry season (Gupta, 2006). This was similar to the distribution pattern in the works of Chattopadhyay *et al.* 2014.

Manganese showed different patterns of distribution in the wet and the dry season. For the dry season, the hot spot of concentration was spotted at three sites (in the north at the control site 1C-2 which was designated as 11, in the south at 1B-6 and 1B-1), whereas during the wet season, the hot spot spread was only found around the 1B-1 site. This could have been as a result of changes in the weather conditions and wind direction (Narayanan, 2009). There was vertical spread of the moderate concentration from the south to up-north cutting across sites 1B-5, 1B-3 and the northern region around the control site in Eket (1C-2). This implied that the Mn pollutant generated must have been spread along the production sites laterally at the dry season. But during the wet season the spread of the Mn pollutant from the 1B-1 source had a lateral spread around the southern area of Eket (Sawford, 1979). The low concentration band had the highest distribution coverage (around the North-Central, to the North – North, North-East, centrally as well as the southern area) at the dry season. This may have been due to the increase wind speed and changes in wind direction (Chen *et al.*, 2016). This differed from the

distribution pattern seen in the works of Asuoha and Osu 2015.

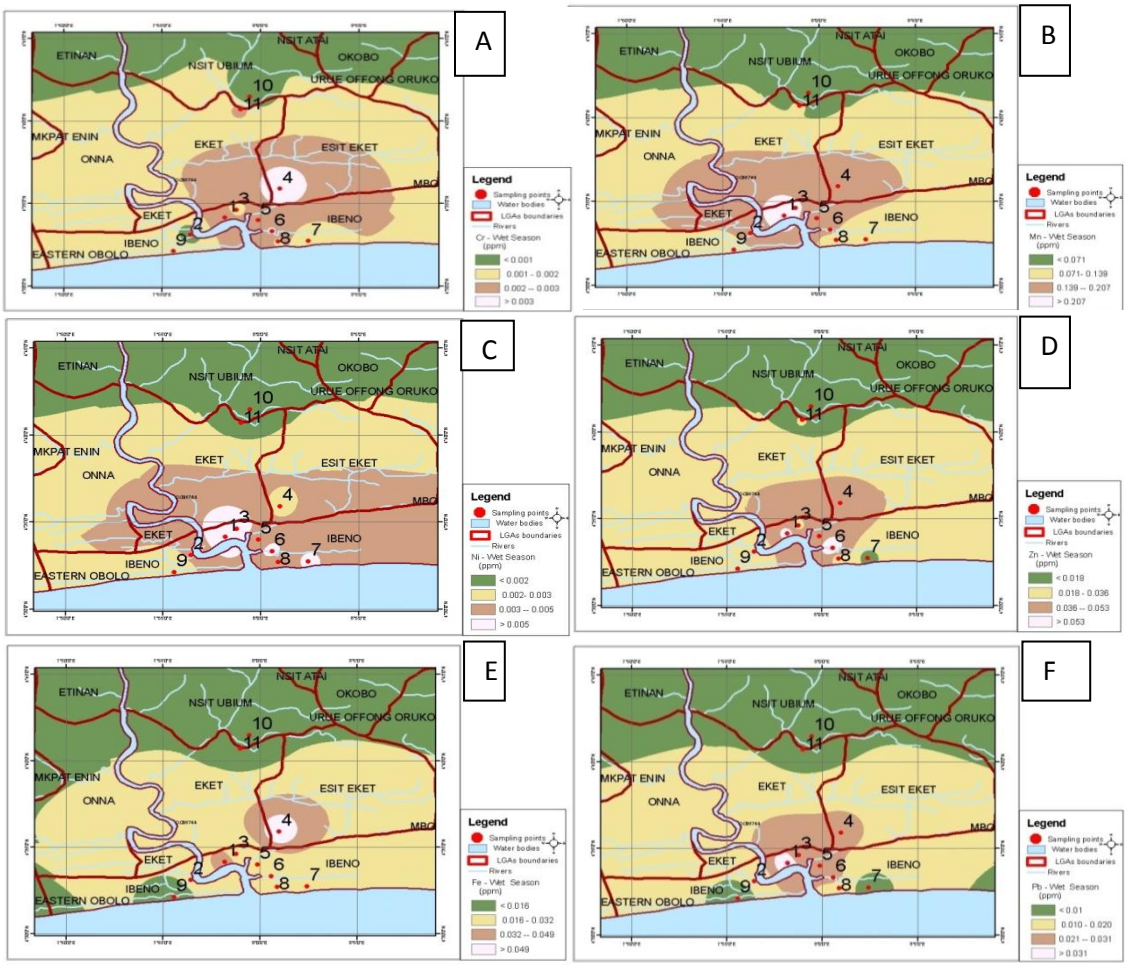

Fig. 4: Spatial interpolation of (A) Cr (B) Mn (C) Ni (D) Zn (E) Fe and (F) Pb in wet season at Ibeno

The very low concentration of Fe during the dry season was seen to almost engulf the entire surrounding cities/villages around Ibeno, and left a narrow coverage area of the very high concentration spread. The very low concentration was found around the industrial area which coincided with the hot spot spread area. A different pattern was recognized at the wet season with a reduced coverage for the very low concentration level. The moderately low concentration level (pigmented yellow) became broader with additional spread which covered the NE and SS areas. The very high concentration (brown pigment) had two unequal splits around the 1B-1 and 1B-4 which may have been due to temperature inversion (Song, 2008), while the hot spot (pink pigment) was concentrated around the IB-4 industrial area. Different concentration levels and distribution was shown in the work of Anh *et al.*, 2014 and Song 2008.

During the wet season, the hot spot for lead was distributed to more locations (1B-7, 1B-1 and IB-3, and 1B-6) than during dry season with just a single spot at the IB-1 (a high traffic and commercial location). Again the moderately high concentration of Pb was more widely spread during the wet season (down south spread) than the dry season (with SS and SE spread). This suggested wider dispersion from the point source and mobile vehicular sources. Another difference in the distribution pattern was seen in the low concentration portions (yellow) at the wet season which covered the central, SE and SE areas, whereas the dry season pattern was more around the central and the SW. Then of course the very low (green pigmented) concentration was seen to differ with more extended coverage across the NE to NW to SS, hence good portion of the central region was occupied by the moderately low (yellow portion) concentration range. Higher concentration and different distribution pattern were shown in the results of Zheng *et al.*, 2015 and Weng and Yang 2006.

Nickel had larger hot spot area coverage at the wet season (with its distribution around 1B-3, 1B-6 and 1B-7) than the dry season (concentrated only around 1B-1 site). The moderately high segment too had wider distribution coverage during the wet season than at dry season which had narrow coverage only around the 1B-1 and 1B-3 sites. Moderately low concentrations of Ni also had a wider spread at the wet season and tended towards the Central-East and Central-West while that for dry season was distributed around the South-Central and South-West. This pattern was different from the pattern in the work of Chen *et al.*, 2016.

Three hot spots were evident in both the dry and the wet seasons with slightly wider coverage during the dry season which was probably due to high wind speed and this was also reflected in better spread for the moderately high portion at the dry than wet season. The moderately low concentration pattern was split into two and this suggested inversion by wind or temperature at the dry and not the wet season (Narayanan, 2009). Similar pattern was seen in the distribution of the very low concentration levels in the works of Zheng *et al.*, 2015 and Javed et al., 2015.

IV. Conclusion

The results of the geo-mapping of the selected trace metals Cr, Zn, Ni, Mn, Fe and Pb in Ibeno, South-south, Nigeria. High spatial distribution was observed in dry and wet season but with comparable mean concentrations throughout the year. Higher concentration of trace metals (Cr, Pb, Ni) were observed around vast areas of the sample locations in the wet season but was not the case for Fe and Zn while Mn had a different pattern in both seasons.

References

[1] Abbasi, N. M. and Tufail, M. (2013). Health risk assessment for heavy elements suspended in dusty air along Murree highway, Pakistan. *Ameriacan-Eurasian Journal of Agriculture and Environmental Sciences*, 13(3):37-377.

[2] Anh, N. K., Phonekeo, V., My, V. C., Duong, N. D. and Dat, P. T. (2014). Environmental hazard mapping using GIS and AHP – a case study of Dong Trieu District in Quang Nihn province, Vietnam. *IOP conference series: Earth and Environmental Science.* Vol. 1, conference1.

[3] Asuoha, A. N. and Osu, C. I. (2015). Seasonal variation of meteorological factors on air parameters and the impact of gas flaring on air quality of some cities in Niger Delta (Ibeno and its environs). *Africa Journal of Environmental Science and Technology*,9(3): 218-227.

[4] Bennet, B. J. (1994). Environmental nickel pathways to man In: Sunderman Jr. F. W. Ed. Nickel in the human environment, Lyon. *Internal Agency for Research on Cancer.* Lyon Pp. 487-495.

[5] Chattopadhyay, S. (2014). Spatial and temporal variations of ambient air quality in Burdwan Town, West Bengal, India. Shodhganga http://dl.handle,net/10603/21860

[6] Chen, H., Lu, X., Gao, T. and Chang, Y. (2016). Identifying hot-spots of metal contamination in campus dust of Xian, China. *International Journal of Environmental Research and Public Health.* 13:555.

[7] Conko, K. M., Rice, C K. & Kennedy, M. M. (2004). Atmospheric Wet Deposition of Trace Elements to a Sub-urban Environment, Reston, Virginia, USA. *Atmospheric Environment.* 38:4025-4033.

[8] Csuros, M. and Csuros, C. (2002). Environmental sampling and analysis for metals. CRC press. Pp129-135.

[9] Dubey, B., Pal, A. K. and Singh, G. (2012). Trace metal composition of airborne particulate matter in the coal mining and non-mining areas of Dhanbad region, Jharkhand, India. *Atmospheric Pollution Research*, 3:238-246.

[10] Ediagbonya, T. F., Ukpebor, E. E. and Okieimen, F. E. (2013). Heavy metal in inhalable and respirable particles in urban atmosphere. *Environmental Skeptics and Critics*,2(3):108-117.

[11] Ediagbonya, T. F., Ukpebor, E. E. and Okieimen, F. E. (2013). Heavy metal in inhalable and respirable particles in urban atmosphere. *Environmental Skeptics and Critics*,2(3):108-117.

[12] Ekpo, B. O., Uno, U. A., Adie, A. P. and Ibok, U. J. (2012).Comparative study of levels of trace metals in moss species in some cities of the Niger Delta region of Nigeria. *International Journal of Applied Science and Technology*,2(3):127-135.

[13] Ekpo, B. O., Uno, U. A., Adie, A. P. and Ibok, U. J. (2012).Comparative study of levels of trace metals in moss species in some cities of the Niger Delta region of Nigeria. *International Journal of Applied Science and Technology*,2(3):127-135.

[14] Emoyan, O. O., Ogban, F. E. and Akarah, E. (2006). Evaluation of heavy metal loading of River Ijana in Ekpan-Warri, Nigeria.*Journal of Applied Science and Environmental Management*, 10(2): 121-127.

[15] Emoyan, O. O., Ogban, F. E. and Akarah, E. (2006). Evaluation of heavy metal loading of River Ijana in Ekpan-Warri, Nigeria.*Journal of Applied Science and Environmental Management*, 10(2): 121-127.

[16] Ewa, E.E., Iwara, A.I., Offiong, V.E., Essoka, P. A. and Njar, G.N. (2013). Seasonal variations in heavy metal status of the Calabar, Cross River State, Nigeria. *Journal of Natural Sciences Research*, 3(11): 2013-78

[17] Faridual, I., Majumdei, S. S., Al Mamun, A., Badiuzzaman, M. A. and Salem, A. (2015). Trace metals concentration of atmopsheric particulate matters in South-East Asian mega city Dhaka, Bangladesh. *Open Journal of Air Pollution*, 4:86-98.

[18] Fomba, K. W., Muller, K., Pinxteren, D. V. and Herrmann, I. (2013). Aerosol sized-resolved trace metal composition in remote northern tropical atlantic marine environment: Case study Cape Verde Island. *Atmospheric Chemistry and Physics*, 13:4801-4814.

[19] Garcia, R., Hart, J. E., Davis, M. E., Reaser, P., Natkin, J., Laden, F., Garshilk, E. and Smith, T. J. (2007).Effect of wind on background particle concentration at truck freight terminals. *Journal of Occupational Environment and Hygiene.* 4(1): 34-48

[20] Garcia, R., Hart, J. E., Davis, M. E., Reaser, P., Natkin, J., Laden, F., Garshilk, E. and Smith, T. J. (2007).Effect of wind on background particle concentration at truck freight terminals. *Journal of Occupational Environment and Hygiene.* 4(1): 34-48

[21] Garrison, V., Lamothe, P., Morman, S. and Plumlee, G. (2010). Trace metal concentrations in african dust: Effects of long distance transport and implications for human health. 19th world congress of soil science and soil solution for a changing world Brisbane, Australia.

[22] Habeebullah, T. M., Said, M., Abdel, H., Awad, A. A., Essam, A. M., Abdulaziz, R. S. and Atif,M. F. (2015). The interaction between air quality and meteorological factors in an arid environment of Makkah, Saudi Arabia. *International Journal of Environmental Science and Development*, (6):76-580.

[23] Hitchins, J., Morawskaa, L., Wolff, R. and Gilbert, D. (2000). Concentrations of sub-micrometre particles from vehicle emissions near a major road. *Atmospheric Environment.* 34(l):51-59.

[24] Hung, I., Deshpande, C. G., Tai, C. and Huang, S. (2005). Spatial and temporal distribution ofvolatile organic compounds around industrial park of Taiwan. *Aerosol and Air Quality Research*, 5 (2): 141-253.

[25] Hung, I., Deshpande, C. G., Tai, C. and Huang, S. (2005). Spatial and temporal distribution ofvolatile organic compounds around industrial park of Taiwan. *Aerosol and Air Quality Research*, 5 (2): 141-253.

[26] Ite, A. E., Udousoro, I. I. and Ibok, U. J. (2014). Distribution of some atmospheric heavy metals in lichen and moss samples collected from Eket and Ibeno Local Government areas of Akwa Ibom State, Nigeria. *American Journal of Environmental Protection.* 2(1): 22-31.

[27] Janour, Z., Zelinger, Z. and Civis, S. (1999). Laser photoacoustic spectrometry and its application for simulation of air pollution in wind tunnel. *Analyst*, 124: 1205-1208.

[28] Jensen, S. S. (1998). Mapping human exposure to traffic air pollution using GIS. *Journal of Hazardous Materials*,61(1-3):385-392.

[29] Kanellopoulou, E. A. (2001). Determination of heavy metals in wet deposition of Athens, global nest: *The International Journal*, 3(l):45-50.

[30] Kariuki, L. W. (2001). Mapping and Analysis of Air Pollution in Nairobi, Kenya. *International Conference on Spatial Information for Sustainable Development.* Kenya National Bureau of Statistics: http://www.knbs.or.ke/censuspopulation.php

[31] Kim, K., Lee, J. and Jang, M. (2002). Metals in airborne particulate matter from the first and second industrial complex area of Taejon city, Korea.*Environmental Pollution*, 118: (41-51).

[32] Kuvarega, A. T.and Taru, P. (2008). Ambient dust speciation and metal content variation inTSP, PM_{10} and $PM_{2.5}$ in urban atmospheric air of Harare Zimbabwe. *Environmental Monitoringand Assessment*, 144:1-14.

[33] Lee, B and Nguyen, T. (2011). Seasonal variation and source of heavy metals in atmospheric aerosols in a residential area of Ulsan, Korea. *Aerosol and Air Quality Research*, 121:679-688

[34] Leilli, M., Naddafi, K., Nabizaab, C. H. R., Yunseian, M. and Mesdayhini, A. (2008). The study ofTSP and PM_{10} Concentration and their heavy metal content in central area ofTehran,Iran. *Air Quality and Atmospheric Health*, 1:159-166.

[35] Mufuyai, G. M., Kamoh, N. M., Kangpe, N. S., Ayuba, S, M. and Eneji. (2015). Heavy metal contamination in roadside dust along major traffic roads in Jos, metropolitan area, Nigeria. *European Journal of Earth and Environment*, 2(1):7-12.
[36] Mahmud, A. T., Siddique, M. N. A., Salam, A. and Shafiqul Alam, A. M. (2008). Temporal variation of atmospheric aerosol particulate matters and heavy metal concentrations in Dhaka, Bangladesh. *Pakistan Journal of Analytical and Environmental Chemistry*, 9(1): 26 –31.
[37] Manoli, E., Voutsa, D and Samara, C. (2002). Chemical characterization and source identification/appointment of fire and coarse air particles in Thessaloniki, Greece. *Atmopheric Environment*, 36:949-961.
[38] Matejicek, L. (2005). Spatial Modelling of air pollution in urban areas with GIS: a casestudy on integrated database development. *Advance Geosciences*, 4: 63–68.
[39] Melaku, S., Morris, V., Raghavan, D. and Hosten, C. (2008) Seasonal variation of heavy metals in ambient air and precipitation, at a single site in Washington, DC. *Environmental Pollution*, 155: 88-98.
[40] Melaku, S., Morris, V., Raghavan, D. and Hosten, C. (2008) Seasonal variation of heavy metals in ambient air and precipitation, at a single site in Washington, DC. *Environmental Pollution*, 155: 88-98.
[41] Moses, K. S., Whiting, V. A., Bratton, R, G., Taylor, J. R. and O'Hara, M. T. (2009). Inorganic nutrients and contaminants in subsistence species of Alaska: linking wildlife and human health. *International Journal of Circumpolar Health*,68(1): 53-74.
[42] Mufuyai, G. M., Eneji, S. E. and Sha'Ato, R. (2014). Concentration of heavy metals in respirable dust in Jos metropolitan area, Nigeria. *Open Journal of Air Polluion*, 3:10-19.
[43] Narayanan, P. (2009). Environmental pollution: Principles, Analysis and Control. CBS Publishers and Distributors PVT Ltd., Pp.18-21.
[44] Nwadinigwe, C. A., Udo, G. J., Nwadinigwe, A. O. and Ubuo, E. E. (2014). Dry and wet seasons dynamics in concentartion of Ni, V, Cd, Pb, Mn, Fe and Co and Zn in soil samples within farmlands in Ibeno coastal area, Akwa Ibom State, Niger Delta Nigeria. *International Journal of Science and Technological Research*, 3(12):2277-2289.
[45] Obioh, I. B., Akeredolu, F. A, Asubiojo, O. I. (1988). National inventory of air pollutants in Efe, Nigeria. Obafemi Awolowo University, Report of the Environmental Research Laboratory.
[46] Ocak, S. and Turalioglu, S. F. (2008). Effect of meteorology on the atmospheric concentrations of traffic-related pollutants in Erzurum, Turkey (2008). *Journal of International Environmental Application and Science*, 3(5):
[47] Okuo, J. M. and Okolo, P. O. (2011). Levels of As, Pb, Cd and Fe in suspended particulate matter (SPM) in ambient air of artisan workshops in Benin City, Nigeria. *Bayero Journal of Pure and Applied Sciences*, 4(2):97 – 99.
[48] Olo Baniyi, S. B and Efe, S. I. (2007). Comparative assessment of rainwater and groundwater quality in anvil product area of Nigeria: Environmental and health implications. *Journal of Environmental. Health and Research*, 6(2):111-118.
[49] Pummakarnchana, O., Tripathi, N. and Dutta, J. (2005). Air pollution monitoring and GIS modeling: A new use of nanotechnology based solid state gas sensors. *Science and Technology of Advanced Materials*, 6: 251–255.
[50] Rana, S. V. S. (2013). *Essentials of Ecology and Environmental Science*. Learning PVT Ltd., p. 385.
[51] Salem, A., Hossain, T., Siddique, M. N. A. and ShafiqulAlam, A. M. (2008). Characteristics of atmospheric trace gases, particulate matter, and heavy metal pollution inDhaka, Bangladesh. *Air Quality and Atmospheric Health*, 1:101–109.
[52] Salem, A., Hossain, T., Siddique, M. N. A. and ShafiqulAlam, A. M. (2008). Characteristics of atmospheric trace gases, particulate matter, and heavy metal pollution inDhaka, Bangladesh. *Air Quality and Atmospheric Health*, 1:101–109.
[53] Sawford, B. L. (1979). Wind Direction Statistics and Lateral Dispersion. *Quarterly Journal of the Royal Meteorological Society*, 105(446):841-848.
[54] Shinggu, D. Y., Ogugbuaja, V. O., Barminas, J. T. and Toma, I. (2007). Analysis of street dust for heavy metal pollutants in Mubi, Adamawa State, Nigeria. *International Journal of Physical Sciences*, 2(11):290-293.
[55] Shrivastav, R. (2001). Atmospheric heavy metal pollution: Development of chronological records and geochemical monitoring. *Resonance*,62: 68.
[56] Song, S. (2008). A GIS-based approach to spatio-temporal analysis of urban air qualityin Chengdu plain. The international archives of the photogrammetry, remotesensing and spatial information sciences Beijing. 37: (B7).
[57] Tawari, C. C. and Abowei, J.F. N. (2012). Air pollution in the Niger Delta area of Nigeria. *International Journal of Fisheries and Aquatic Sciences.* 1(2):94-117.
[58] Theodosi, C., Markaki, Z., Tselepides, A. and Mihalopoulos, N. (2010). The significance of atmospheric inputs of soluble and particulate major trace metals to the eastern mediterranean seawater. *Marine Chemistry*. 120:154-163.
[59] Tillet, T. (2010). Another mechanism behindcadmium toxicity impaired NAT- dependent pathway alters chemical biotransformation. *Environmental Health Perspectives*, 118(12):A543
[60] Tripathi, R. M., Vinod, K. A., Manikandan, S. T., Bhalke, S., Mahadevan, T. N. and Puranik, V. D. (2004). Vertical distribution of atmospheric trace metals and their sources atMumbai, India. *Atmospheric Environment*, 38:135–146.
[61] Tsai, C., Aggarwal, S. G., Chang, C. andHung, I. (2004). concentration profiles of acidic and basic air pollutants around an industrial part of Taiwan. *Water, Air and Soil Pollution*, 151(1-4):287-304.
[62] Tsai, C., Aggarwal, S. G., Chang, C. andHung, I. (2004). concentration profiles of acidic and basic air pollutants around an industrial part of Taiwan. *Water, Air and Soil Pollution*, 151(1-4):287-304.
[63] Uno, U. A.1., Ekpo, B. O., Etuk, V. E., Etuk, H. S. and Ibok, U. J. (2013). Comparative study of levels of trace metals in airborne particulates in some sities of the Niger Delta region of Nigeria. *Environment and Pollution*, 2(1): 110.
[64] Uno, U. A.1., Ekpo, B. O., Etuk, V. E., Etuk, H. S. and Ibok, U. J. (2013). Comparative study of levels of trace metals in airborne particulates in some sities of the Niger Delta region of Nigeria. *Environment and Pollution*, 2(1): 110.
[65] Weiwei, L. V., Yanxin, W., Xavier, Q., Xinguo, Z., Andres, A., Angel, L. and Mar, V. (2006). Geochemical and statistical analysis of trace metals in atmospheric particulates in Wuhan, central China. *Environmental Geology*, 51:121–132.
[66] Weng, Q. and Yang, S. (2006). Urban air pollution patterns, land use and thermal landscape: An examination of the linkage using GIS. *Environmental Monitoring and Assessment*, 117: 463–489.
[67] Wu, Y. F., Liu, Q. C., Tu, L. (2008). Atmospheric deposition of metals in TSP of Guiyang,PR China. *Bulletin of Environmental Contamination and Toxicology*, 80:465–468.
[68] Xiao-li, S., Yu, P., Hose, G.C., Jian, C.and Feng-xiang, L. (2006). Spider webs as indicators for heavy metals pollution in the Air.*Bulletin of Environmental Contamination and Toxicology*, 76:271-277.
[69] Yang, H., Chen, P., Hsieh, L., Lin, M. and Huang, K. (2003). characteristic of atmospheric metals during dry monsoon season in the coastal region of western Taiwan. *Aerosol and Air Quality Research*, 3(1):29-39.
[70] Zereini, F., Alt, F., Messerschmidt, J., Wiseman, C. Feldmann, I., Bohlen, A. V., Muller, J., Liebl, K., and Puttmann, W. (2005). Concentration and distribution of heavy metals in urban airborne particulate matter in Frankfurt am Main, Germany. *Environmental Science and Technology*, 39(9):2983-2989.
[71] Zheng, X., Zhao, W., Yan, X., Shu, T., Xioning, Q. and Chen, F. (2015). Pollution characteristics and health risk assessment of airborne heavy metals collected from Beijing bus stations. *International Journal of Environmental Research and Public Health*, 12:19658-19671.