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Assessment of Heavy Metals Distribution and Contamination in Atmospheric Dust from Major Roads in Ado-Ekiti, Ekiti State using Pollution Indices

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***Abstract*— Atmospheric dust samples from major roads in Ado-Ekiti, Ekiti State, Nigeria were analyzed for heavy metals. The heavy metals were determined using atomic absorption spectrometer (AAS) Buck Scientific model 210VGP. The overall mean of the concentrations of heavy metals assessed in the samples were in the order Zn > Mn > Pb > Ni > Cu > Cr. Pollution indices such as contamination factor, enrichment factor, ecological risk factor and geo-accumulation index were used to evaluate the heavy metals concentrations in the dust. Result of contamination factor indicated that the degrees of contamination are moderate to considerate except Ni with very high value of contamination factor while enrichment factors are deficiency to moderate. All heavy metals assessed showed low ecological risk and the index of geo-accumulation of the metals in the dust samples were found within uncontaminated to moderately contaminated level except Mn which was extremely contaminated base on value computed. This confirmed that the dust from the urban area is facing probable environment pollution with dangerous heavy metal.**

***Index Terms*— Contamination factor, Enrichment factor, Ecological risk factor, Geo-accumulation Index, Ado-Ekiti.**

I. INTRODUCTION

Environmental pollution is one of the biggest threats to human existence on this planet, increasing with every passing year and causing terrible and irreparable damages to the earth. It has existed for several centuries but only started to attract global attention following the industrial revolution in the 19th century. Pollutants find their ways into the environment either by natural occurrence or anthropogenic means. Heavy metals are released and became deposited into the environment through human activities such as industrial activities, agricultural activities, domestic wastes, mining activities and emissions from vehicles and factory [1]. The recent development in industrial and commercial activities such as transportation has been on the high rate to aid and promote production process. Improper handling of these processes results in the geochemical cycling of heavy metals. Vehicle exhausts, as well as several industrial activities emit these heavy metals while soils, plants and even residents along roads with heavy traffic loads are subjected to increasing levels of contamination with heavy metals [2]. Soil, a custodian of heavy metals, is the preeminent reservoir, carrier and donor of most biologically active elements such as Lead, Cadmium, Iron, Arsenic, Chromium, Nickel, Silver, and Zinc that reach man through plants and animals. The alteration of
natural sources as a result of human activities, temperature changes, acidification, plant rooting, erosion, weathering process [3] and various changes in climatic condition during different season often determine how active these heavy metals are.

Nigeria, like every other West African country, has two major seasons: the dry season and the rainy season. The dry season popularly known locally as harmattan usually occurs between the end of November and mid of March. The season is characterize by dry and dusty [4], low humidity and desert-like weather condition. The conditions contribute significantly to environmental pollution. During this period, dust mobility rate is higher because the particulate matters are dried and lighter especially the road side dust. Road dust, having received varying inputs of contaminants from diversity of natural or artificial sources such as emission from vehicles, power plants, industrial plants, oil burning, waste incineration and construction activities as well as from surrounding contaminated soils is geared by the weather conditions to move around rapidly [5][6]. The level of environmental pollution is determined by the composition and quantity of chemical matrix of road dust [7].

Over the years, several studies have been conducted on the assessment of heavy metals in the soil and dust in relation to human health [8][6][3][9] but little consideration has been on the study during harmattan season. However, the objective of this present study is to use different approaches involving contamination factor, enrichment factor, ecological risk factor and geo-accumulation index to interpret the findings on heavy metals in road side dust from major roads in Ado-Ekiti, Ekiti State, Nigeria during harmattan season.

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II. Materials and Method

Study Area

The study was conducted on major roads in Ado-Ekiti. Ado-Ekiti is the capital of Ekiti State in southwest, Nigeria. The city lying in latitude 7.6333 and longitude 5.21667 with the total land mass 293 km^2 (113 sq mi) has a pollution density of 424,340 [10]. The average annual temperature in Ado Ekiti is 25.1 °C and averages annual rainfall of 1334 mm. The city is house to two universities, three polytechnics and two school of nursing. Ado-Ekiti is a commercial centre and the mode of transport is by road

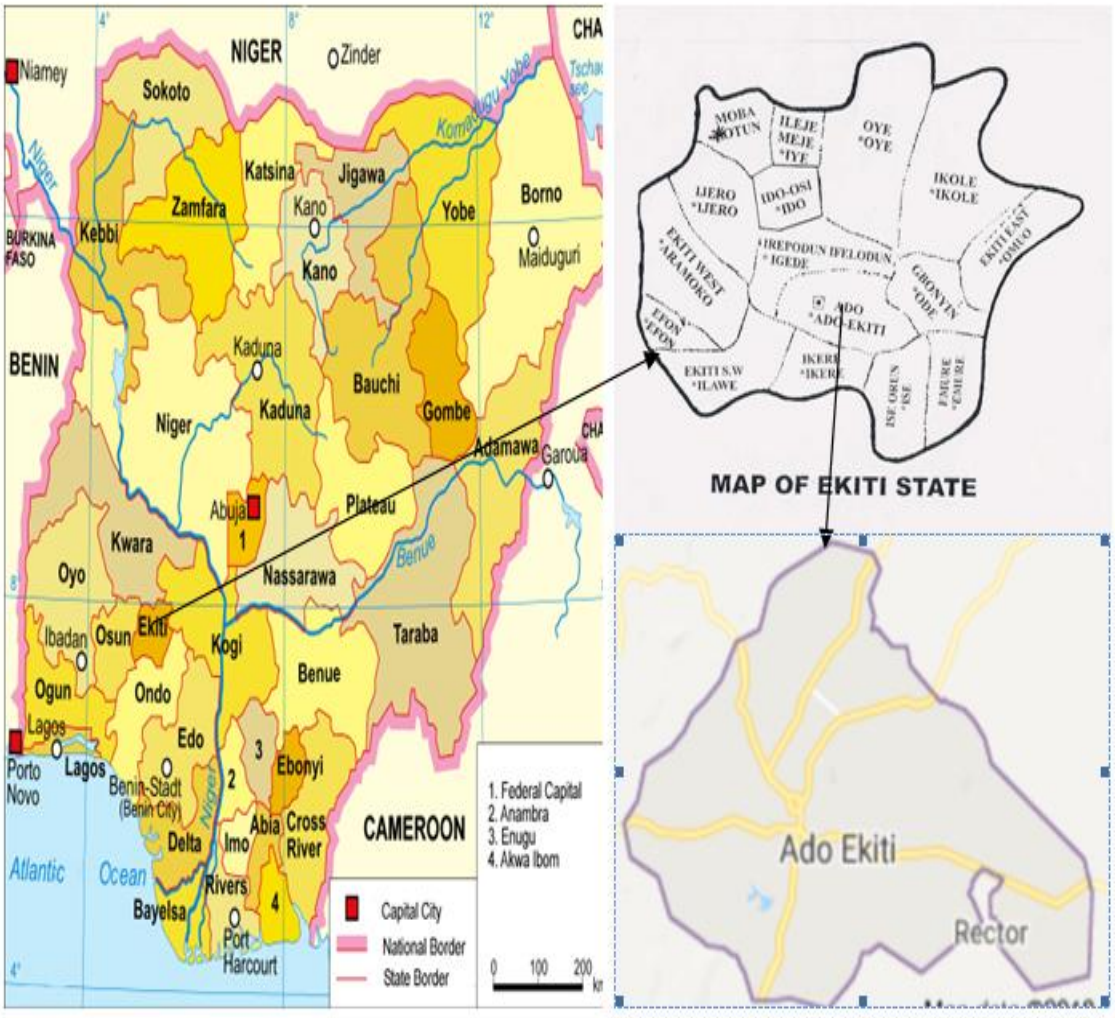

Fig 1: Map of Nigeria, Ekiti State and Ado-Ekiti Source: Ekiti.com

Sample Collection

Six atmospheric dust samples were collected from six major roads in Ado-Ekiti. The sample were taken in Adebayo, Iworoko road (A), Bashiri, Iyin road (B), Federal Housing Afao road (C), Abe Aba, Ilawe road (D), Ajebandele, Ikere road (E), Polytechnic, Ikare road (F) while control sample(G) was obtained from a site at Rector Village, Federal Polytechnic campus, Ado-Ekiti.

A well cleaned, dried and labeled bowl of about 50 cm high and 30cm in diameter was placed at each sampling point along the road for 8 hours (9am to 5pm local time) in January, 2018 (at the peak of harmattan period). The bowl was used to avoid disturbance and contamination of the sample by passer-by and animals. The samples were transferred into clean polythene bags and transported to laboratory for further treatment and analysis.

Sample Code	Cordinates	Street Name
A	N 7°41'20.1768" E5°15'10.9656"	Adebayo, Iworoko road
B	N 7°40'43.1004" E5°11'31.0416"	Bashiri, Iyin road
C	N 7°38'48.4728" E5°15'2.484"	Federal Housing, Afao road
D	N 7°36'57.1068" E5°10'58.3104"	Abe Aba, Ilawe road
E	N 7°33'25.812" E5°12'49.3056"	Ajebandele, Ikere road
F	N 7°35'58.9344" E5°18'14.6088"	Polytechnic, Ikare road
Control	N 7°35'40.2468" E5°17'10.014"	Rector Village, Federal Polytechnic, Ado-Ekiti Campus

Fig 2: Samples Locations. Source: Google map

Sample Preparation

The dust samples were air-dried to constant weight and homogenized. The sample was sieved through 500 µm stainless steel mesh wire. The sample digestion was done using method reported by [11]. 1.0 g dust sample was transferred into a digestion flask and digested using 20ml freshly prepared aqua regia (mixture of hydrochloric acid and nitric acid in ratio 3:1) in a fume compound. The flask was covered with inverted funnel to control excessive evaporation of the acid mixture. When the content become clearer and reduced to about 5 to 10 ml, the flask was removed from the hotplate, cooled to room temperature and filtered, washed with de-ionized and double-distilled water and transferred quantitatively into a 50 mL volumetric flask and made up to the mark with distilled water. The heavy metals were determined using atomic absorption spectrometer (AAS) Buck Scientific model 210VGP. All chemicals used were of analytical grade.

Pollution Indices

Pollution index is a simple and generalized method to predict and communicate to the public the level of pollution in the environment. It is calculated from several sets of pollution data. For this present study, contamination factor, pollution load index, enrichment factor, ecological risk factor and geo-accumulation index were employed to assess the level of heavy metal pollution in roadside dust from the major roads in Ado-Ekiti during harmattan season.

Contamination factor

Contamination factor (CF) is used to express the level of contamination of roadside dust. It can be calculated using equation stated below:

$$C = \frac{\text{Cm Sample}}{(\text{Cm Background})} \quad (1)$$

Where CF is the contamination factor, C_m is the concentration of a given metal in the dust and C_m Background is the concentration of metal in a control sample. The terminologies used to describe contamination factor [12].

Enrichment factor

Enrichment factor (EF) has been used by many researchers to assess level of contamination in various samples [13] [12] [14] [15] [16]. For this study, enrichment factor was calculated using the following equation [13]:

$$EF = \frac{[Me/Fe]sample}{[Me/Fe]background} \quad (2)$$

where $(Me/Fe)_{sample}$ is the metal to Fe ratio in the sample of dust from roadside; $(Me/Fe)_{background}$ is the background value of metal to Fe ratio. An element is considered as a reference element if it has low occurrence variability and is present in the element in trace amounts [9]. In this research work, Fe was considered as reference element because of the attribute. Categories of enrichment factor that exist [13] are given on table 1.

Ecological Risk Factor

Ecological risk factor is employed to investigate the

probability of adverse effects from the release of a particular chemical pollutant into the receiving environment. This was calculated using the equation suggested by [17].

$$E_r = T_r \times C_f \quad (3)$$

Where T_r is the response coefficient for the toxicity of a given metal, C_f is the contamination factor. Toxic response for Zn, Mn, Cr, Cu, Co, Pb, Ni, As and Cd are 1, 1, 2, 5, 5, 5, 5, 10 and 30 respectively [17].

The terminologies used to describe ecological risk factor [12] are presented in table 1.

Index of Geo-accumulation (I_{geo})

Geo-accumulation index has been used by environmental researchers to assess the level of metal pollution in a sample of interest [7][18][19]. This is done by comparing the current level of metal concentrations of the sample with pre-industrial level. Geo-accumulation index was calculated using the equation defined by Muller in 1969 [20].

$$I_{geo} = \log_2 [\frac{Cm\ Sample}{1.5\ x\ Cm\ Background}] \quad (4)$$

Where Cm = measured concentration of metal of interest in a sample

Cm background = geochemical background concentration of the metal

The factor 1.5 was introduced in the equation to correct possible variations in the background values. The descriptive classes of I_{geo} value as proposed by [21] are given on table 1.

Table 1: Different types of model and the categories for the description of soil contamination

Model	Class	Description
Contamination factor	Cf < 1	Low contamination factor
	1 ≤Cf <3	Moderate contamination factor
	3 ≤ Cf < 6	Considerate contamination factor
	Cf > 6	Very high contamination factor
Enrichment factor	EF < 2	deficiency to minimal enrichment
	2 ≤ EF < 5	moderate enrichment
	5 ≤ EF < 20	significant enrichment
	20 ≤ EF < 40	high enrichment
	EF ≥ 40	extremely high enrichment
Ecological Risk Factor	Er< 40	Low potential ecological risk
	40 ≤ Er< 80	Moderate potential ecological risk
	80 ≤Er < 160	Considerate potential ecological risk
	160 ≤ Er< 320	High potential ecological risk
	Er ≥ 320	Very high potential ecological risk
Index of Geo-accumulation (I_{geo})	I_{geo} value	I_{geo} Class
	0	0 Uncontaminated
	0 – 1	1 Uncontaminated to moderately contaminated
	1 – 2	2 moderately contaminated
	2 – 3	3 moderately to strongly contaminated
	3 – 4	4 strongly contaminated
	4 – 5	5 strongly to extremely contaminated
	5 < I_{geo} value	6 extremely contaminated

III. Results and Discussion

Table 2: Distribution of Heavy Metal in Dust Samples investigated and Basic Statistical analysis.

Sample location	Cu	Mn	Cr	Ni	Pb	Zn
Iworoko Road	33.67b	64.00b	10.09a	56.07a,b	60.80a	162.67a
Iyin Road	26.01a	53.33a	9.18a,b	54.69a,b	59.22a	130.02d
Afao Road	29.33c	57.08a	8.07a,c	61.02b,c	43.30b	148.22b
Ilawe Road	27.81a,c	55.67a	9.22a,b	43.47d	54.10a,b	138.00c
Ikere Road	34.67a,b	69.01a,b	8.67a,b,c	45.10a,b,c	56.67a	151.84b
Ikare Road	41.00a	73.43a	7.46c	5c1.87c	58.43a	133.33c,d
Min	26.01	53.33	7.46	43.47	43.30	130.02
Max	41.00	73.43	10.09	61.02	60.80	162.67
Mean	32.08	62.09	8.78	52.04	55.52	144.01
SD	5.26	7.76	0.97	6.72	7.03	11.89
Control	17.54	21.38	4.48	38.22	16.42	26.10

Table 3: Single pollution indices of average values of metal concentrations of roadside dust samples from major roads in Ado-Ekiti

Heavy metal	Contamination factor		Enrichment factor		Ecological risk factor		Index of Geoaccumulation		
	Value	Description	Value	Description	Value	Description	Value	Class	Description
Cu	1.829	Moderate contamination	0.830	deficiency to minimal enrichment	4.150	Low potential ecological risk	0.286	1	Uncontaminated to moderately contaminated
Mn	2.904	Moderate contamination	1.320	deficiency to minimal enrichment	1.320	Low potential ecological risk	6.432	6	Extremely contaminated
Cr	1.960	Moderate contamination	0.890	deficiency to minimal enrichment	1.780	Low potential ecological risk	0.386	1	Uncontaminated to moderately contaminated
Ni	7.744	Very high contamination	0.620	deficiency to minimal enrichment	3.100	Low potential ecological risk	-0.140	0	Uncontaminated
Pb	3.381	Considerate contamination	1.540	deficiency to minimal enrichment	7.700	Low potential ecological risk	1.173	2	moderately contaminated
Zn	5.518	Considerate contamination	2.510	moderate enrichment	2.510	Low potential ecological risk	1.411	2	moderately contaminated

Table 4: The Spearman's rho correlation coefficient between metals concentrations in the samples zones.

		Cu	Mn	Cr	Ni	Pb	Zn
Spearman's rho	Cu	1					
	Mn	**.948****	1				
	Cr	-.300	-.257	1			
	Ni	-.121	-.152	.040	1		
	Pb	.284	.278	.432	-.063	1	
	Zn	.455	**.480***	.298	.127	.092	1

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table 2 summarizes the heavy metals distribution, range, mean, standard deviation and the analysis of variance and compared the values with the control sample. The value computed for each sample was the average of triplicate determinations. The average of Cu concentrations in the samples ranged from 26.01 to 41.00 mg/kg, Mn concentrations ranged from 53.33 to 73.43 mg/kg, Cr concentrations ranged from 7.46 to 10.09 mg/kg, Ni concentrations ranged from 43.47 to 61.02 mg/kg, Pb concentrations ranged from 43.30 to 60.80 mg/kg and Zn concentrations ranged from 130.02 to 162.67 mg/kg.

Overall value of the mean concentration of heavy metals in the sample is in the order of Zn > Mn > Pb > Ni > Cu > Cr. The distribution of heavy metals in the samples was as follow: Ikare Road: highest Cu, Mn and lowest Cr concentration; Iworoko Road: highest Cr, Pb and Zn concentration; Afao Road: highest Ni and lowest Pb concentration; Iyin Road: lowest Cu, Mn and Zn concentration; Ilawe Road: lowest Ni concentration. The mean values of the heavy metals of the samples showed greater values than heavy metal in the control sample.

Higher values of heavy metal in the samples as compared to control sample were due to anthropogenic influence on the sample. The is expected since the dust samples were obtained from the road side with heavy traffic rate causing release of exhaust from fuel engine combined with dust emanated from untare/poorly tarred roads with poor drainage system and aided by unfavourabbly weather condition that influence the movement of the dust particles in air. However, the source of Zn to the dust sample may be from galvanized part of vehicle, lubricating oil, tyres as well as Vehicle brake [22]. Pb is introduced mainly from automobile exhaust (Paggio, et al.,

2009), from gasoline and vehicular emission. Source of Ni into roadside dust is believed to be as a result of corrosion of vehicular parts [9]. Cu finds its way into the dust from mechanical part of vehicles. , Cr in roadsides dust is believed to be due to corrosion of vehicular parts [18]. Source of Cr in roadsides dust can be accounted for as due to corrosion of vehicular parts and industrial activities from chemical and tanning industries [18]. Activities of road side mechanics, painters, panel beaters and other roadside artisans also have inputs.

Results of the pollution indices are presented in table 3. The results showed a moderate contamination factor for Cu, Mn and Cr, considerate contamination for Pb and Zn and indicated very high contamination for Ni. This could be as a result of wear and tear of vehicular parts which introduces nickel into the soil. The enrichment factor of Cu, Mn, Cr, Ni and Pd showed a deficiency to minimal enrichment while the value computed for Zn showed moderate enrichment. Evaluation of ecological risk factor indicated that the environment has low potential ecological risks for all the heavy metal assessed. Geoaccumulation index results gave the classes of Ni, as 0, Cu and Cr as 1, Pb and Zn as 2 and Mn as 6 indicating uncontaminated, uncontaminated to moderate contaminated, moderated to contaminated and extremely contaminated respectively.

Table 4: The Spearman's rho correlation coefficient at heavy metal assessed in the atmosphere dust of Ado-Ekiti indicated that the Cu correlated significantly and positively with manganese and Mn/Zn is moderately significant. Such significant correlation indicates that the paired elements have a common contamination source. The rest of the elemental pairs show no significant correction with each other.

IV. CONCLUSION

The distribution of heavy metals in atmospheric dust along major roads in Ado-Ekiti has been determined. The average value of the heavy metal concentrations were in the order Zn > Mn > Pb > Ni > Cu > Cr and were found higher than the values of the heavy metal in the control sample. This suggests that the dust has been contaminated through various anthropogenic means. Various pollution index tools used for the evaluation indicated that the atmospheric dust pose low health risk except from Ni as predicted by contamination factor while geoaccumulation index analysis showed that the dust is extremely polluted by Mn. The difference in the results the pollution indices may be due to the difference in sensitivity of these indices towards the dust sample [23]. This confirmed that the duct is facing potential environmental pollution with dangerous heavy metal (Ni and Mn) as a result of anthropogenic inputs.

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