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Heavy Metal Content in Soil in Garki Area Council of Federal Capital Territory, Abuja, Nigeria

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Abstract

This study investigates the concentration of Heavy Metals in soil sample from 15 different locations in Garki area of Federal Capital Territory (F.C.T) Abuja, Nigeria. The level of Cu, Cd, Pb, Ni, Mn, and Zn were determined using flame atomic absorption spectrophotometer. The results obtained indicated that these metals on dry weight basis in the soil ranged between (36.60-525.0 µg/g) Pb, (15.00-74.40 µg/g) Cu, (17.50-29.80 µg/g) Zn, (0.7-2.20 µg/g) Cd, (16.16-24.60 µg/g) Ni, and (270-558.0 µg/g) Mn. From the results, areas with high traffic density seem to be relatively high in concentration of tested metals than those from less traffic density. A significant correlation was found between traffic density and metal concentrations. The soil PH of the sample sites varies on the average from 6.44 to 7.24 in water indicating only a slightly acidic to neural. Generally, the concentrations obtained were higher than the tolerable limit for safe environment as prescribed by Nigeria Federal Environmental Protection Agency (FEPA) and World Health Organization (WHO).

Keywords: Heavy metals; Soil; concentration; Traffic density

Introduction

Ever since life began on earth, the atmosphere has been an important resource for chemicals elements and a medium for deposition of wastes. The deposition of waste in the atmosphere will lead to change in the natural levels of chemical substances in the atmosphere and hence causes pollution of the atmosphere. Pollution is defined as the introduction by man into the environment, substances or energy liable to cause hazard to human health, harm to living resources or amenity or interference with legitimate uses of environment [1]. Any substance which is present in nature beyond permissible limits, as well as has detrimental effects not only on the environment but also on living organisms is called Pollutant [2]. Emission from Heavy traffic on roads contains lead (Pb), cadmium (Cd), zinc (Zn) and nickel (Ni), which are present in fuel as anti-knock agents [3,4].The deposition of vehicle derived metal and the relocation of metals deposited on road surface by air and runoff water have led to contamination of soil [5-8]. The level of lead in petrol in Nigeria was estimated as 0.7 g/liter and the national Consumption of petrol in the country is estimated at 20 million liters per day with about 150 people per Car [9]. It was therefore predicted that at least 15,000 kg of lead is emitted into the environment through burning [10]. Hence, automobile exhaust were believed to account for more than 80% of the air pollution and lead content in Nigeria's super grade gasoline is 600 – 800 mg/liter [11,12], which is much higher than permissible levels in some pollution conscious countries. Analysis of household dust in Sydney suggests that lead in "contaminated" households can originate from either gasoline or paint, depending on the proximity to major traffic thoroughfares and Pb in household dust is more consistent with gasoline lead [13]. Sources of lead by the road side was attributed to the settled out from burned leaded gasoline, settle dust from industrial sources and lead around houses from lead paint that has been scraped off during the continuing repainting of the house [14]. Smoking of cigarettes, cosmetics and paint chips could result in elevated Cd, Zn and Cr content [15]. It was proved that worn construction; furnishing and carpet materials can lead to elevated heavy metal content [16]. Nickel is one of many trace metals widely distributed in the environment, with both natural and anthropogenic sources. It finds its way into the ambient air as a result of the combustion of coal, diesel oil and fuel oil, the incineration of waste and sewage, and miscellaneous sources. Tobacco smoking in the form of gaseous nickel carbonyl, Stainless steel in kitchen, inexpensive jewelry utensils also contributes to lower level of nickel [17]. Carcinogenic transition metals such as Ni and Cu catalyze the generation of reactive oxygen species that may result in damage to cell membranes, mitochondria, proteins and DNA [18]. The excessive Mn exposure is associated with neurologic and neuropsychiatric disorders, including the subclinical signs and symptoms of Parkinsonism, reduced speed of movements, and alterations in gait, posture and facial expressions [19]. Pb at low levels causes nausea, irritability while large dose causes brain damage [20]. Low levels of Cd (0.2 mg/day) cause hypertension, and degenerative bone disease at high levels [21]. Zn Deficiency cause dwarfism, dermatitis, loss of taste, immature gonads and delay wound healing, its toxicity causes anemia [22]. Contamination of soils by Heavy Metals (HM) is the most serious environmental problem and has significant implications for human health [23]. The environmental problems associated with Heavy metal pollution have increased during the last decade. It has become increasing evident that this type of pollution is affecting plants, human, and animals resources. Thus, the aim of this study is to investigate the level of heavy metals including Pb, Mn, Cu, Ni, Cd and Zn in Garki Area of Abuja and to elucidate the relationships between the levels of metals in these areas and traffic density.

Study area

Abuja, the Federal Capital Territory (F.C.T) is located in the geographical center of Nigeria and lies between longitudes 60 45 and 70 45E and latitudes 80 25 and 90 25N.The total landmass of Abuja is 713 sqKms and it is bounded to the south by kogi state, northwest by Niger, south- east by Nasarawa and Kaduna in the north –east. The

population of Abuja as at 2006 census was 776,298 [24]. Although this figure would have been exceeded as at 2015.

Materials and Methods

Sampling sites

Fifteen sites were selected for the study from Garki area of F.C.T. These sampling sited were chosen to reflect commercial, residential, public office areas with peculiar characteristics like refuse dumps. The volume of traffic per hour was determined for all the sites. Table 1 below shows the description of samples sites and their traffic density.

Sampling preparation/treatment of soil sample

Characteristics and road side soils were taken (3 m away) from fifteen different locations in Federal Capital Territory - F. C. T representing areas of different traffic density. The volume of traffic per hours was computed for different areas by taking a traffic census over a period of 12 hours for seven days between 0700 -1900 h daily. The results were used to categorise the areas into high (above 1000 per hour), and low (below 1000 per hour) traffic density areas. The sampling was carried out both during the dry and rainy seasons of the year. Sample (in duplicate) were collected at the distance not more than 3 m from the road side. The samples were kept in polythene bags. They were dried in an oven at about 80%c. the dried samples were ground in porcelain motar, and sieved with 2 mm size nylon. The fraction passing through the sieve were subsequently store and used for metal determination using a pye unican atomic absorption spectrophotometer model sp9 in the flame mode.

PH determination

Each soil sample was mixed with water in a ratio of 1:5. This was allowed stand for about hours, after which it was then filtered and the pH meter was used to determine the pH.

Determination of organic carbon

This was carried out by the dichromate method. 10 ml of 0.167 M $K_2Cr_2O_7$ solution and 20 ml of H_2SO_4 – $AgSO_4$ solution was added 0.5 g of sample in 500 ml conical flask and heated gently to 1500°C within one minute. It was allowed to cool and the excess $K_2Cr_2O_7$ was determination back-titration with $FeSO_4$ solution after dilution to 200 ml and the addition of 10 ml 85% H_3PO_4, 0.2 g NaF, and 30 drops of diphenylamine indicator. A blank analysis was also carried out with each series of samples in other to assess the impact of reagents to metal levels [25].

Metal determination choice of method

Two methods of samples preparation were used to prepared a sample for metal determinations. This was to test the extraction efficiency of the methods. The first method was described by Anderson and it involved subjection of 5 g of the soil to 3 hours constant extraction with 2 M HNO_3 acids [26]. The second method was described by HO and Tai and it involved treating 1 g of the soil sample with 10 ml of 14 M HNO_3 acid. This was heated in steam bath were it was evaporated to dryness and then cooled. The procedure was repeated with another 10 ml of 14 M HNO_3 followed by 10 ml of 12 M HCl [27].The digested soil sample was then warmed in 20 ml of 14 M HCl to re-dissolve the metal salt. The mixture was finally filtered and the filtrate was diluted to 25 ml in a volumetric flask with distilled water. The results obtained with the methods are listed in Table 2. A comparison of the two methods shows that the means were significantly different (t-test) at 95% confidence interval. Since the second method showed much lower results, the Anderson method was therefore used to prepare all other samples prior to metal determination.

Results and Discussion

Tables 3 and 4 showed the PH and organic carbon content of the soils from all sites. Data presented in these Tables indicated that soils have a low organic matter (0.66%) mean value. Soil pH value ranged between 6.44 and 7.24 with an average of 6.97 in water indicating only a slightly acidic to neural. Acidic nature of the soil could be attributed to the effect of bush burning and the harmatten dust [28]. The mean concentrations of Pb, Cu, Zn, Cd, Ni and Mn elements in soil samples are summarized in Table 5. Soil samples generally show a high level of

METAL	METHOD I (µg/g) DRY. Wt.[26]	METHOD II (µg/g) DRY. Wt.[27]
Pb	38.10 ± 13.7	24.13 ± 7.92
Mn	119.93 ± 17.0	45.13 ± 17.6
Cu	1.50 ± 4.0	1.90 ± 0.4
Zn	12.68 ± 0.13	1.11 ± 1.1
Cd	0.38 ± 1.5	0.27 ± 0.1
Ni	2.81 ± 1.5	14.20 ± 1.2

Table 2: Comparison of Means levels by the Extraction Methods.

Sample	PH	% of organic carbon	Pb	Cu	Zn	Cd	Ni	Mn
			Concentration(µg/g)					
AA	6.85	1.20	525.0	26.3	23.3	1.5	18.8	281.3
BB	6.94	1.19	319.3	28.9	22.4	1.1	19.5	427.0
CC	7.01	2.51	380.6	25.2	24.0	1.5	18.1	558.0
DD	7.22	0.48	424.8	21.8	22.6	1.7	19.6	390.5
EE	7.09	0.45	388.5	32.8	25.5	1.5	19.0	382.0
FF	7.04	0.36	36.6	19.3	27.0	2.1	20.1	411.3
GG	6.95	0.18	309.0	15.0	23.8	2.2	18.8	399.0
HH	7.06	0.30	174.5	15.9	17.5	1.3	16.1	270.0
II	7.24	0.33	354.8	27.0	28.6	1.6	19.6	462.5
JJ	7.05	0.80	305.6	74.4	21.3	0.7	17.0	296.3
EEE	6.44	-	290.0	18.3	24.0	1.5	19.0	408.0

Table 3: Metal Level In Soils at Commercial Areas (High Traffic Density) Sites.

Sample	PH	% of organic carbon	Pb	Cu	Zn	Cd	Ni	Mn
			Concentration(µg/g)					
AAA	7.07	0.18	433.0	58.6	29.8	1.1	21.0	486.0
BBB	6.88	0.18	273.0	18.3	21.3	1.4	23.0	454.0
CCC	6.90	-	393.0	26.3	23.5	1.8	24.6	500.0
GGG	6.80	0.36	385.0	35.0	27.5	1.8	20.3	424.0

Table 4: Metal Level in Soils at Residential /Public office (Low Traffic Density) Sites.

Sample	Description of sites	Traffic census / hour
AA	Area 1 traffic light	3160
BB	Area 2 traffic light	2696
CC	Area 10 traffic light	4200
DD	International conference center	1440
EE	Area 11(equatorial trust bank limited)	2968
FF	Central district area	3132
GG	National assembly quarters	3552
HH	City gate	1200
II	Area 11(FCDA secretary)	1836
JJ	Area traffic light	3588
AAA	Area 1(along Sokoto street)	396
BBB	Area 2(along okene street)	216
CCC	Area 10 (Nipost corperate headquarters)	288
EEE	Area 11 (along yelwa street)	1032
GGG	Inside national assemble quarters	480

Table 1: Description of Samples Sites and their Traffic Density.

	TD	Pb	Cu	Zn	Cd	Ni	Mn
TD	1						
Pb	0.792	1					
Cu	0.791	0.337	1				
Zn	0.753	0.460	0.410	1			
Cd	0.964	0.510	0.004	0.316	1		
Ni	0.019	0.575	0.669	0.242	0.286	1	
Mn	0.500	0.658	0.725	0.050	0.396	0.020	1

TD = Traffic Density

Table 5: correlation between heavy metals in soil and traffic density

	TD	Pb	Cu	Zn	Cd	Ni	Mn
TD	1						
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Cu	0.791	0.337	1				
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Mn	0.500	0.658	0.725	0.050	0.396	0.020	1

TD = Traffic Density

Table 6: correlation between heavy metals in soil and traffic density

Trace metal	DPR µg/g	FEPA µg/g	WHO µg/g
Cd	0.01	0.01	0.005
Cr	0.03	0.03	0.02
Pb	0.05	0.05	0.05
Ni	0.1	0.1	0.5

Table 7: DPR, FEPA, and WHO, permissible limits

metals concentration. The range of heavy metals concentration found in soil was 0.7 to 558 µg/g. This results obtained indicated that, these metals on dry weight basis in the soil ranged between (36.60-525.0 µg/g) Pb, (15.00-74.40 µg/g) Cu, (17.50-29.80 µg/g) Zn, (0.7-2.20 µg/g) Cd, (16.16-24.60 µg/g) Ni, and (270-558.0 µg/g) Mn. Pb concentration in soil shows a mean of 332.8 µg/g and a range of 36.60 to 525.0 µg/g. The value of Pb in all the samples areas was found to be high except in the central district area which shows a low level of Pb 36.6 µg/g. This value however, is higher than the maximum value obtained for Zn, Cd, and Ni except for Mn and Cu. The range value for Pb (36.60-525.0 µg/g) is lower than (89.9 -754.4 µg/g) in Bauchi soils [29], 1,925 mg/kg Pb in Urban soils of amman, Jordan [30] and 1,999 mg/kg Pb in urban soils of Sidney, Australia [31] but higher than 0.013 ± 0.006-0.225 ± 0.020 µg/g in soils of Malaysia [32], (10.06 ± 0.36 – 29.71 ± 1.56 mg/kg) in Aba soils [33] and 280 mg/kg in soils of Honolulu, USA [34].The high Pb content of the soil could be attributed to vehicular emissions as well as metal plating and lubricating oils. It could also be due to rough surfaces of the roads which increase the wearing of tyres, and run-offs from the roadsides [35]. Lead pollution in urban soil has been attributed to combustion of gasoline that contains tetraethyl lead as anti-knock agent [8,36-38]. It was revealed by Atuanya et al. [39] that higher lead concentration in soils has toxic effect on microorganisms inhabiting the soil which consequently alters the flora and fauna of a location. Lead has been found to be the major cause of hypertension, impairment of central nervous system and other respiratory problems in adult [40]. Zinc and Pb are amongst the metal referred to as common urban pollutants [41,42]. The fragmentation of tires has been implicated for higher concentrations of Zn in heavy traffic zones [43,44]. The concentration of Zn was found in the range of (17.50-29.80 µg/g). The level of Zn in this study is lower than 9.0-400 mg/kg obtained in urban

soils of Poznan municipality, Poland [45], 0.90-169 mg/kg in Florida soils [46], 58 -330 mg/kg in roadside soils of Dortmund, Germany [47] but higher than 0.774 ± 0.070-13.40 ± 1.52 in soils of Malaysia [32]. The ranged value for Cd in the soil sample was 0.7 – 2.20 µg/g, the level of Cd in this study higher than 0.006 ± 0.002 - 0.030 ± 0.005 µg/g in soils of Malaysia [31]. As such the source of Cd in soil may be attributed to vehicular emissions. Cadmium is released as a combustion product in the accumulators of motor vehicles or in carburetors [48,49]. The main concentration of Ni in the soils determine were within the ranged of 16.16 µg/g and 24.60 µg/g and the mean nickel content in soils, of the world vary between 8-33 and 20-92 µg/g for light and heavy soils respectively. Ni concentration determined in the present study remained within the target Values of 35 mg/kg and lower than EU value [50,51]. Soil generally contains 200 – 3000 mg/kg of manganese with an average value of 600 mg/kg [52]. The levels of manganese in this study were relatively high. The highest level of manganese obtained was 558.0 µg/g which is higher than what was reported in Bauchi (419.1 µg/g) [29] and in Kaduna (132 mg/kg) [53]. But lower than the results obtained in the United States (2532 mg/kg), China (1740 mg/kg), Poland (1122 mg/kg) and Yauri (608.11 mg/kg) [54-57]. Mn and Ni are associated with traffic related sources such as corrosion of metallic part, concrete materials, reentrained dust from roads and tear and wear of tyres and engine parts [58]. The correlation coefficient between the concentrations of heavy metals in soils and traffic density in the study area is summarized in Table 6. The correlation analysis of the results for heavy metals concentrations in soil samples indicated a significant correlation between traffic Density and Zinc with correlation value of $(r2=0.753)$ and $(r2=0.964)$ for Zn and Cd respectively. This value indicates that automobile tires are also sources of Cd in the environment [28]. It was also found a significant correlation between concentrations of Pb and Cu in the soil sample with $(r2=0.79)$. The high level of Pb which correlated with traffic density confirmed that automobile emission is the major sources of Pb in this study area. There was no correlation between traffic density and Ni. The non-significant correlation signified that these metals might have resulted from sources other than vehicular emission [32]. From the results, the metal concentration values are arranged in the decreasing order: CMn > CPb > CCu > CZn > CNi > CCd where C stands for concentration. The concentration level of the heavy metals determined in the present study was significantly higher than the soils permissible limits as prescribed by WHO, 1971, DPR 1991, FEPA, 1991. Table 7 for the safe environment [59-61].

Sources DPR (1991), FEPA (1991), and WHO (1971).

Conclusions

In this study, Heavy Metals (Pb, Cu, Zn, Cd, Ni and Mn) concentration in soil in Garki area of Federal Capital Territory, Abuja, Nigeria, was investigated. The results obtained showed that the soil samples from various site have a high level of heavy metals concentration. The result also showed a positive correlation between heavy metals and Traffic density indicating that emission from automobile is majorly responsible for such level of pollution.

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