International Research Journal of Pure & Applied Chemistry
4(5): 486-493, 2014

SCIENCEDOMAIN ***international***
www.sciencedomain.org

Distribution Pattern of the Heavy Metals: Pb, Zn, Cd and Cu in Roadside Soils of Maiduguri Metropolis, Borno State Nigeria

S. T. Garba[1*], I. Ahmed[1], J. C. Akan[1] and B. A. Dauda[1]

[1]Department of Chemistry, P. M. B. 1069, University of Maiduguri, Borno State, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Author STG designed the study, performed the statistical analysis and wrote the first draft of the manuscript. Authors IA and BAD collect the samples and managed all the analyses of the study. Author JCA managed the literature searches and wrote the protocol. All authors read and approved the final manuscript.

Original Research Article

Received 8th March 2014
Accepted 17th April 2014
Published 6th May 2014

ABSTRACT

In this research work the level of the metals: Pb, Cd, Zn, and Cu were determined in soil samples collected within Maiduguri Metropolis. Samples were collected from places of high anthropogenic activity such as automobile maintenance workshop (AMW), Car park or Bus stops (CP), and the highways (HW) to places of low activity the Residential areas (RA) at the depth of 5 to 15cm. To avoid washing away by rainfall, all collections were done during the dry season in the month of September/October 2012 to April/May of the following year 2013. These periods are period of incessant wind and sandstorm marked with low or no rainfall in this part of the country (far north-eastern part of Nigeria). Soil samples were analyzed using ICP-OES following digestion with aqua-regia and the results shows that; the AMW has the highest level of 180.96±3.84 μgg^{-1} for the metal Pb, whereas the levels, 200.15±10.81, 124.05±6.52, and 1.39±1.28 μgg^{-1} for the metals: Zn, Cu, and Cd respectively were observed in the samples from the Highways. Residential areas received the lowest values of 93.28±3.66, 26.76±3.43, and 0.40±0.54 μgg^{-1} for the metals; Cu, Pb and Cd respectively. The least value 113.82±16.02 μgg^{-1} for Zn was observed in the samples from the car parks or bus stops. The variation of the level of

**Corresponding author: Email: stelagarba@yahoo.com;*

contamination by the metals: Pb, Cd, Cu and Zn with the high levels from places of high anthropogenic activity indicate the high level of contribution by vehicles. It also showed that the level of the metals observed in the samples from the residential areas may be attributed to atmospheric deposition of the metals carried from the highly anthropogenic places or from extraneous sources and not only a function of soil type.

Keywords: Pollution; automobiles; traffic; car parks; residential area; power generating plant.

1. INTRODUCTION

Pedos means soil in Greek and the term pedosphere is used to donate the soil cover, the terrestrial part of the earth. Soil is the main component of the biosphere, the vital layer of our planet. It is populated by various organisms ranging from tiny bacteria to higher plants, animals and human. It provides the means of physical support for all terrestrial organisms. Its physical and chemical properties vary considerably with geographical locations, depending on the parent material, climate and the type of weathering [1].

Our environment has always been under natural stresses but its degradation was not as severe as it is today. In recent years there has been increasing concern around the world over chemicals in the environment. This is in response to information on the wide spread distribution of chemicals stemming from human activities and the potential harmful effect of those chemicals to human or on the ecological system which sustain humans. As nations developed industrially, the production and use of chemicals rises in parallel to the standard of living and consequent increase in life expectancy [2]. Heavy metal is a general term describing a group of elements with a density of 5 g/cm^3, having atomic weight between 63.54g and 200.59g, and a specific gravity greater than 4 [3]. Of these, Fe, Mo and Mn are important as micronutrients, while Zn, Ni, Cu, Co, Va and Cr are toxic elements, but have importance as trace elements. Silver (Ag), As, Hg, Cd, and Pb have no known biological function as nutrients, and seem to be toxic to plants and microorganism [4]. The majority of the heavy metals are toxic to the living organism and even those considered as essential can be toxic if present in excess. They can impair important biochemical process posing a threat to human health, plant growth and animal life [5,6,7]. Studies have shown that such pollutants can be harmful to the roadside vegetation, wildlife and the neighboring human settlements [8, 9,10,11].

Metal toxicity and the danger of their bioaccumulation in the food chain represent one of the major environmental and health problems of our modem society. Unlike organic substances which are degradable, even at extremely low concentration heavy metals may cause serious diseases in human beings. For example, Pb poisoning can cause neurologic and behavioral disorders, learning and concentration difficulties. In severe cases, the affected person may suffer from acute psychosis, confusion and reduced consciousness [5,12]. Cu and Zn are essential elements in the human body, but excess doses of them will cause diseases. Copper for instance causes vomiting, gastrointestinal bleeding, acute tubular necrosis, and hemolytic anemia [13]. Most heavy metals are emitted from anthropogenic sources; industry and industrial wastes, transport, manure and herbicides used in agronomy, as well as sewage silt [14]. However, in urban areas it has been reported that automobile exhausts emission is one of the potent contributions. These metals are released during different operations such as combustion, component wear, fluid leakage and corrosion of metals. Lead, cadmium, copper and zinc are the major metal pollutants of the roadside environments and are released from burning of fuel, wearing out of tyres, leakage of oils, and corrosion of batteries and metallic parts such as radiators etc. [15,16,17,7].

Sakagami et al. [18] reported that there was a close relationship between trace metal concentration in roadside soil and those in the dust falls. Trace metals in the soils can also be re-suspended in the air in the form of dusts, which may affect the air quality [19]. While the route of exposure to atmospheric aerosols is by inhalation, exposure to toxic substances in the soil is mainly by ingestion. It has been observed that in most developing countries where pollution are especially high a large number of children lives on the roadside and spend most of the day on the street in condition of poor hygiene picking up objects from the soil and chew them [1]. Therefore, studies on urban heavy metal accumulation are of great significance to the region's environmental protection and human health safety. Hence the need to determine the level of the metals: Cu, Pb, and Zn in Maiduguri Metropolis, the capital of Borno state, Nigeria.

2. EXPERIMENTALS DESIGN

2.1 Sample and Sampling Sites

Samples were collected within Maiduguri metropolis. Four different sampling sites were designated for this study, these include: Car parks or bus stop (CP) this covers; tashan Bama Motor Mark (Mari), Tashan Baga Motor Park (Baga Road), Tashsn Kano Motor Park (Maduganari), maiduguri Terminus and Tashan Joni all within Maiduguri Metropolis. Highways (HW) this site includes; the highway from Post Office to Tashan Baga; from Post Office to Tashan joni (Air port Road); from custom to the University compus; these are the bussiest roads within the Metropolis. Automobile Maintenance workshops (AMW) this site includes: The Bank of the north area of post office, Dauda mechanic workshop area of Leventis super market, and the automobile maintenance workshop around the flour mill area. The sites represent areas of high anthropogenic activities. The residential areas (RA), include the sites; Jiddari Polo ward, Silimri ward, Sulemanti ward and Kafanti ward. These sites represent the areas of less activity. Five different composite and homogenized samples were collected for each sampling site. Samples were collected at the depth of five to fifteen centimeters from the surface and at the intervals of two meters apart using broom and hand trowel. To avoid washing away by rainfall, all collections were done during the dry season in the month of September/October 2012 to April/May of the following year 2013. These periods are period of incessant wind and sandstorm marked with low or no rainfall in this part of the country (far north-eastern part of Nigeria). Samples collected were preserved in an acid prewashed cleaned polyethylene bags for subsequent analysis.

2.1.1 Sample preparation and analysis

Samples collected were homogenized, dried at 60℃ t o a constant weight, grounded into fine powder using an acid pre-washed mortar and pestle and sieved through a 2mm nylon sieve [7]. Analysis was done using ICP-OES following digestion with 10 mL Aqua regia [16] in a digestion tube, for the level of the metals: Pb, Cu, Zn, and Cd, in the soil samples.

2.1.1.1 Statistical data handling

All statistical data handling were performed using SPSS 17 package. Differences in heavy metal concentrations among the different sites of sampling were detected using One-way

ANOVA, followed by multiple comparisons using Tukey tests. A significance level of (P = 0.05) was used throughout the study.

3. RESULTS AND DISCUSSION

The Table 1 shows the levels of the metals observed in the soil samples sampled within the Maiduguri Metropolis. Of all the elements determined, Zn has the highest level of 200.15 ±10.81 and was found in the sample from the highways. The least value 113.82±16.02 of this metal (Zn) was observed in the sample from the car parks or bus stops. The highest level of Cu (124.05μgg^{-1}) was observed from the automobile maintenance workshop whereas the least value (93.28±3.66) was found in the samples from the residential areas. The highest level of Pb (41.83±4.54) was observed in the sample from the highways. Whereas the least value ((26.76±3.43) was found in the samples from the residential areas. And of all the elements determined in this study Cd has the least level of contamination (0.41±0.57) and this was observed in the samples from the residential areas. The highest level of contamination of this metal Cd (1.39±1.28) was observed in the samples from the highways.

Table 1. Mean ± SD concentration (μgg^{-1}) of the Heavy metals: Pb, Zn, Cd and Cu, in Maiduguri Metropolis

Sample	AMW ± SD	CP ± SD	HW ± SD	RA ± SD
Pb	180.96±3.84	37.15±7.01	41.83±4.54	26.76±3.43
Zn	142.86±7.51	113.82±16.02 **a**	200.15±10.81	120.11±9.29
Cd	1.21±1.51	0.56±0.41	1.39±1.28	0.41±0.57
Cu	112.80±2.33	102.87±9.54 **a**	124.05±6.52	93.28±3.66

Means with the same letter within a column are not significantly different at (P = .05) according to the Tukey test. Data are presented in mean ±SD (n = 5) = Standard deviation of five different samples, AMW = Automobile maintenance workshop, CP = Car Park or Bus stop, HW = Highway, RA = Residential Area

The distribution pattern of the heavy metal pollutants determined in this study within Maiduguri Metropolis varies from a place of high anthropogenic activity such as the mechanical workshops, car parks or bus stops and the high ways to a place of less anthropogenic activity such as the residential areas. The mechanical workshop for instance, there are various sections or units that deals with the constructions of vehicle body where filing and welding of metals, scrapping and re-paintings of the vehicle body takes place. Engine repair another unit where diesel, gasoline and lubricating oils spills. All these, coupled with corrosion of batteries and metallic parts such as radiators, rusting and oxidation of organic compounds have resulted into the release of these metals into the environment. Hence the level: 180.96±3.84; 142.86±7.51; 1.21±1.51 and 112.80±2.33 μgg^{-1} for the metals; Pb, Zn. Cd and Cu respectively determined in the samples from the automobile maintenance workshop as shown in Table 1 above. It has been reported that heavy metal pollutants such as Cd, Cu, Pb and Zn originated mainly from gasoline, car component, oil lubricants and vehicle/industrial incinerator emissions [20,7].

In the Car Parks or bus stops, the level of the metals (Pb, Cu, Cd and Zn) observed was found higher than even what was observed from the mechanical workshops. Apart from the atmospheric gravitational deposition of these particles, the high level of these metals from these sites could be due to traffic density, high rate of warming engines (combustion), leakage of oils, wearing out of tyres due to repeated brakes coupled with the high temperature and the nature of our roads, might have contributed to the release and high levels of the pollutants (Pb, Cu, Cd and Zn). It has been reported that heavy metals are released due to weathering of the road surface asphalt and corrosion of crash barriers and road signs [21]. This has confirmed that, in the urban environment, the greater source of the metals, Pb, Cu, Cd and Zn is linked to industrial operations, traffic and its density, rate of emission and the speed at which the vehicles operate as reported by [22,23,11]. More so most of the vehicles operating in the car parks or bus stops are poorly managed or aged ones. It has been reported that older vehicles will emit more pollutant than a newer ones, if they are not properly maintained [24].

On the highways, although the number of vehicles operating on the highways is greater than that in the car parks, the speeds at which they operate also contribute. The level of the metals determined in the samples from these sites (Table 1) therefore was found at a higher level than what was observed in the car parks, and the residential areas (Table 1). In the present study, the concentration of zinc for instance, in samples from the highways was found to be twice the background level (the residential areas) as shown in Table 1. This may be due to the higher input of zinc in the roadside environments by motor vehicles. Kiekens [25] stated that the total zinc levels in polluted soils in industrialized countries may account for hundred to thousand times higher than those in unpolluted soils. Most automobiles emission comprise of different fraction particles. These fractions include the ultrafine particles which are formed in the engines and tailpipes, fine particles produced mainly by chemical reactions and coarse particles which are formed mechanically by the abrasion of road materials, tyres and brake linings [26,27] has contributed to the high levels of the metals determined in the samples from this site. The sources of Cd in the urban areas are much less well known than those of Pb, Cu, Ni, etc. But metal plating and tire enforced with metals were considered the likely common anthropogenic sources of the metal in the environment through burning of tyres and bad road surfaces. Other sources of cadmium and zinc are found in lubricating oils as part of many additives. It was reported that the cadmium level in car tyres is in the range of 20 to 90 (µg/g) as associated Cd contaminations in the process of vulcanization [28]. Hence the high level of Cd observed in the samples from the highway (Table 1). Alloway [29] mentioned that 0–1 µg/g of cadmium in soils indicates non-contamination, 1–3 µg/g indicates slight contamination and 3–10 µg/g indicates a contaminated soil. Table 2 shows the comparison of heavy metals (µgg^{-1}) along the highway in Maiduguri Metropolis with those of some cities/countries of the world.

The residential areas which in this study serves as the control or the background used in the comparison of the heavy metals (Pb, Zn, Cu, and Cd), showed drastic reduction in their concentrations. The level of the metals at this sampling site has further confirmed that the heavy metal input on the highways, car parks or bus stops, and the automobile maintenance workshops, originated mainly from gasoline, car component, oil lubricants and vehicle/industrial incinerator emissions as reported by [20,17,7,15]. This sampling site is characterized by less traffic activity though there are sparsely distributed household powers generating plant. The level of the pollutants observed could therefore be attributed to the atmospheric gravitational deposition of these metals or the natural existence of the metals in the soil. Although the level of contamination by the metals in residential area of this study is very low compare to the remaining sampling site, these values were however found higher than what was observed in other studies conducted elsewhere. The level of Pb for instance in this study observed in the samples from the residential (26.73) was found higher than 20.37 and 17.69µg g^{-1} observed in the residential areas of Mubi and Lagos respectively [30,33] but very much lower than 61.34 µg g^{-1} observed in Egypt [39].

Table 2. The comparison of heavy metals (μgg^{-1}) along the Highway in Maiduguri Metropolis with those of some cities/countries of the world

City/Country	Pb	Cd	Cu	Zn
This study	41.83	1.39	124.05	200.15
Mubi/ Nigeria [30]	121.53	0.67	25.06	206.64
Jos/Nigeria [31]	12.10	5.79	2.19	12.88
Enugu/Nigeria [32]	31.00	2.80	64.00	-
Lagos/Nigeria [33]	69.20	-	-	198.32
Bhilai city/India [34]	813.20	-	-	-
Kathmandu/Nepal [35]	245.36	2.84		
Dubai/United Arab Emirates [36]	308.09	1.01	18.04	170.27
Kalava/Greece [37]	300.90	0.20	-	-
Birmingham/ UK [38]	48.00	1.68	-	-

4. CONCLUSION

This study has shown that Maiduguri Metropolis is relatively contaminated with heavy metals. The level of contamination varies and decreases from place of high anthropogenic activities (automobile maintenance workshops, the Car Parks or bus stops, and the highways) to a place of less or no anthropogenic activities (the residential areas). Automobile, powers generating plant and metal construction works could be responsible for the high levels of the metals along the high ways, the car parks and the automobile maintenance workshops. Since their levels was found to increase with increasing traffic density due to poor and insufficient road networks and of metal construction works. The low level of these metals (Pb, Cd, Cu and Zn) in the residential areas may be attributed to atmospheric deposition of the metals from extraneous sources and not only a function of soil type. Finally, results obtained from this research work would now provide significant reference value for future studies of these areas and other regions in Borno state.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCE

1. Radojevic M, Bashkin V. Practical environmental analysis. The Royal Society of Chemistry London; 1999.
2. United Nations Environmental Program. Chemical pollution. A Global Review United Nations Environmental Program Geneva; 1992.
3. Gardea-Torresdey JL, De La Rosa G, Peralta-Videa JR, Montes M, Cruz-Jimenez G, Cano-Aguilera I. Differential uptake and transport of trivalent and Hexavalent chromium by tumbleweed *(Salsola kali).* Arch Environ Contam. Toxicol. 2005: PMID: 15696348
4. Nies DH. Microbial heavy metal resistance. Appl Microb Biotech. 1999;51:730-860.
5. Jarum L. Impact of environmental pollution on health: Balancing risk. British Medical Bulletin. 2003;68:167-182. DOI: 10.1093/bmb/ldg032
6. Silva ALO, Barrocas RG, Jacob SC, Moreira JC. Dietary intake and health effects of selected toxic elements. Brazilian Journal of Plant Physiology. 2005;17:79–93.

7. Ikenaka Y, Shouta MMN, Kaampwe M, Kennedy C, Hiroki T, Naoharu M, Mayumi I. Heavy metal contamination of soil and sediment in Zambia. Afr J Env Sci Tech. 2010;4(11):729-739.
8. Iqbal MZ, Shafiq M, Ali SF. Effect of automobile pollution on seed germination and branch length of some plants. Turkish Journal of Botany. 1994;18:475–479.
9. Ferretti M, Cenni E, Bussotti F, Batistoni P. Vehicle induced lead and cadmium contamination of roadside soils and plants in Italy. Chemistry and Ecology. 1995;11:213–228.
10. Turer D, Maynard JB, Heavy metal contamination in highway soils. Comparison of Corpus Christi, TX and Cincinnati, OH shows organic matter is key to mobility. Clean Technology and Environmental Policy. 2003;4:235–245.
11. Nakayama MMS, Ikenaka Y, Muzandu K, Choongo K, Oroszlany B, Teraoka H, Mizuno N, Ishizuka M. Heavy Metal Accumulation in Lake Sediments, Fish (*Oreochromis niloticus* and *Serranochromis thumbergi*) and Crayfish (*Cherax quadricarinatus*) in Lake Itezhitezhi and Lake Kariba, Zambia. Arch Env Contamin Toxicol. 2010;59(2):291-300.
12. Jakubowski M, Low-level environmental lead exposure and intellectual impairment in children-The current concepts of risk assessment. Int J Occup Med Environ Health. 2011;24:1-7. DOI: 10.2478/s13382-011-0009-z. [PubMed] [Cross Ref]
13. Fisher DC, Copper. In: Sullivan JB (Jr), Krieger GR. Clinical Environmental; 2001.
14. Fargasova A. Root growth inhibition, photosynthetic pigments production and metal accumulation in Sinapis alba as the parameters for trace metals of effect determination. Bull Environ Contam Toxicol. 1999;61:762-769.
15. Li X D, Poon CS, Pui SL. Heavy metal contamination of urban soils and street dusts in Hong Kong. App Geochem. 2001;16:1361-1368.
16. Akbar KF, Headley AD, Hale WHG, Athar M. Heavy metals contamination of roadside soils of northern England. Soil Water Res. 2006;4:158-163.
17. Baker JM, Ochsner TE, Venterea RT, Griffis TJ. Tillage and soil carbon sequestration-what do we really know? Agr Eco Env. 2007;118:1-5.
18. Sakagami KI, Eamada R, Kurobe T, Heavy metal contents in dust fall and soil of the National Park for Nature Study in Tokoyo. Mitteeilungen der Deutschen Bodenkundlichen Gessellscaft. 1982;33:59-66.
19. Gray CW, Mclaren RG, Roberts AHC, Atmospheric accessions of heavy metals to some New Zealand pastoral soils. Sci Total Environ. 2003;305:105-115.
20. Popoola OE, Bamgbose O, Okonkwo OJ, Arowolo TA, Odukoya O, Popoola AO. Heavy metals content in playground topsoil of some public primary schools in metropolitan Lagos, Nigeria". Research Journal of Environmental and Earth Sciences. 2012;4(4):434-439.
21. Van Bohemen HD, Van de Laak WHJ. The influence of road infrastructure and Traffic on Soil, Water and Air Quality. Environmental Management. 2003;31(1):50-68.
22. Dolan MS, Clapp CE, Allmaras RR, Baker JM, Molina JAE. Soil organic carbon and nitrogen in a Minnesota soil as related to tillage, residue and nitrogen management. Soil and Tillage Res. 2006;89:221-231.
23. Bai J, Cui B, Wang Q, Gao H, Ding Q. Assessment of heavy metal contamination of roadside soils in Southwest China. Stoch Environ Res Risk Ass; 2008. DOI 10.1007/s00477-008-0219-5.
24. Niirjar RS, Jain SS, Parida M. Development of transport related air pollutants modeling for an urban area. Journal of Indian Road Congress. 2002;487.
25. Kiekens L, Zinc. In: Alloway BJ (ed.). Heavy Metals in Soils. Chapman & Hall, London. 1995;284–303.

26. Palmgren F, Waahlin P, Kildesó J, Afshari A, Fogh CL. Characterisation of particle emissions from the driving car fleet and the contribution to ambient and indoor particle concentrations. Phys Chem Earth. 2003;28:327-334.
27. Olukanni DO, Adebiyi SA. Assessment of vehicular pollution of road side soils in Ota Metropolis, Ogun State, Nigeria. IJCEE-IJENS. 2012;12(4):40-46.
28. Yu KN, Yeung ZL, Kwok RCW Determination of Multi-element Profiles of Soils using Energy Depressive X-Ray Fluorescence (EDXRF). Appl Radiat Isot. 2003;58:339-346.
29. Alloway BJ. Heavy Metals in Soils. Chapman & Hall, London. 1995;284–303.
30. Shinggu DY, Ogugbuaja VO, Barminas JT, Toma I. Analysis of street dust for heavy metal pollutants in Mubi, Adamawa State, Nigeria. Inter J Phy Sci. 2007;2:290-293.
31. Abechi ES, Okunola OJ, Zubairu SMJ, Usman AA, Apene E. Evaluation of heavy metals in roadside soils of major streets in Jos metropolis, Nigeria. Journal of Environmental Chemistry and Ecotoxicology. 2010;2(6):98-102.
32. Ekere NR, Ukoha OP. Heavy metals in street soil dusts of industrial market in Enugu, South East, Nigeria. International Journal of Physical Sciences. 2013;8(4):175-178. DOI: 10.5897/IJPS12.719.
33. Olukanni DO, Adeoye DO. Heavy Metal Concentrations in Road Side Soils from Selected Locations in the Lagos Metropolis, Nigeria. International Journal of Engineering and Technology. 2012;2(10):1743-1752.
34. Ambade B. Evaluation of heavy metal contamination in road dust fallout of Bhilai City. Int J Adv Engg Res Stud. 2012;1:81-83.
35. Raj SP, Ram PA. Determination and Contamination Assessment of Pb, Cd and Hg in Roadside Dust along Kathmandu-Bhaktapur Road Section of Arniko Highway, Nepal. Research Journal of Chemical Sciences. 2013;3(9):18-25.
36. Aslam J, Khan SA, Khan SH. Heavy metals contamination in roadside soil near different traffic signals in Dubai, United Arab Emirates. Journal of Saudi Chemical Society. 2013;17:315-319
37. Christoforidis A, Stamatis N. Heavy metal contamination in street dust and roadside soil along the major national road in Kavala's region. Greece, Geoderma. 2009;151:257–263.
38. Charlesworth S, Everett M, McCarthy R, Ordonez A, De Miguel E. A comparative study of heavy metal concentration and distribution in deposited street dusts in a large and a small urban area: Birmingham and Coventry. West Midlands, UK, Environ Inter. 2003;29:563-573.
39. El–Sayed AE, Girgis BR, Rajab MH, Nassar ES. Trace metal Concentrations in Street Dust Samples in Zagazig City, Egypt and Their Risk Assessment. Proceeding of Fifth Scientific Environmental Conference, Zagazig UNI. 2010;37-47.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=500&id=7&aid=4482