OPEN ACCESS
Chemistry & Material Sciences Research Journal
Volume 3, Issue 1, P.No. 6-14, January, 2021
DOI: 10.51594/cmsrj.v3i1.203
Fair East Publishers
Journal Homepage: www.fepbl.com/index.php/cmsrj

INDEX MODELS ASSESSMENT OF HEAVY METAL CONTAMINATION IN SOIL SAMPLES OF SELECTED MOTOR PARKS WITHIN MAIDUGURI, BORNO STATE, NIGERIA

[1]A.I. Mohammed, [2]A.A. Ahmed, & [3]J.U. Jibrin
[1,2,3] Department of Pure and Applied Chemistry, University of Maiduguri, PMB 1069, Maiduguri, Borno State, Nigeria

*Corresponding Author: A.I. Mohammed

Article Received: 20-12-20 **Accepted:** 25-01-21 **Published:** 31-01-21

ABSTRACT

Heavy metal pollution is a global issue of concern which results from both biogenic and anthropogenic activities. Hence, an investigation of soil pollution is pertinent because of its potential threat to human health. The present study examined the concentrations, contamination and pollution load index cum ecological risk factor for some heavy metals in soil samples collected from Borno Express (BOEXP), Tashan Kano (TASKP) and Tashan Bama (TASBP) motor parks within Maiduguri, Borno state of Nigeria. The data obtained showed mean concentration range of 0.34 - 1.18 mg/kg, 0.04 - 0.15 mg/kg, 0.07 - 0.41 and 0.18 - 0.29 mg/kg for Zn, Cr, Cd and Cu respectively. Nonetheless, lead was not detected in any and all samples analyzed. The increasing order of concentrations in the soils followed: Zn > Cu > Cr > Cd, Cu > Cd > Zn > Cr and Cd > Zn > Cu > Cr for BOEXP, TASKP and TASBP motor parks respectively. Notwithstanding, the results showed lower concentrations to the allowable limits of World Health Organization (WHO). Furthermore, the contamination factor of cadmium in the TASKP fell within the (0.10 – 0.25) category, indicative of slight contamination whereas in TASBP, the calculated value 0.5125 was within (0.51 -0.75) category implying severe contamination. The other heavy metals analyzed showed contamination factor as well as pollution index values < 0.1 indicative of very slight contamination.

Keywords: Borno Express, Tashan Kano, Tashan Bama, Motor Parks, Contamination Index.

INTRODUCTION

Pollution of heavy metal is a global threat to the environment as they are widely present in earth, air, water and food (Fifield and Haines, 2000). In urban soils and road dusts, the anthropogenic sources of heavy metals include traffic emission (vehicular exhaust particles, attrited tyre and brake lining particles), industrial emission from power plants coal combustion, metallurgical industry auto repair shop, chemical industry, etc, weathering of building, domestic emission atmospheric deposit and so on (Solgi, 2016).

Sources of toxic heavy metals in the environment are from both geological and anthropogenic sources (Diskshith and Diwan, 2003). Soil can be contaminated with heavy metals from natural sources which include weathering of soil, sediments and rocks, sandstorms, major rest fires and volcanic eruptions (Waidron, 1980). Anthropogenic sources of toxic metals include mining, smelting, coal and petroleum processing, municipal sewage discharges, household waste incineration, solid waste disposal sites, phosphate fertilizers, leas-arsenic pesticides leaching, chipping or peeling of paint from old structures are sources of heavy metals in the soil (Salt *et al.,* 1995). In the past years, several studies have been carried out on soil pollution due to toxic heavy metals as a serious worldwide health and environmental problem. In Nigeria, like other developing countries, improved road accessibility creates a variety of supplementary employments which range from vehicle repairs, vulcanizer welders to auto electrician, battery charges and other facilitators of motor transportation. These activities contaminate soils with heavy metals (Sulaiman *et al.*, 2018; Oyeleka *et al.*, 2016).

The study of heavy metals levels in urban soils provides baseline information about anthropogenic sources of pollution, behavior of the metals in different soils, basis for planning strategy to accomplish a better environment quality and substantial development of the city. Because of the importance of parks and green areas, special attention has been be paid to study the heavy metals contamination in urban parks.

Objective of the Study

The objective of the study was to analyze soil samples from three motor parks within Maiduguri, Borno state, Nigeria for levels of heavy metals and assess their contamination/pollution indices in terms of heavy metals.

MATERIAL & METHODS

Materials

Chemicals used in the study were of reagent grade and used as received. These include; HCl, High Purity HNO_3, hydrogen peroxide. All preparations were done using deionized water.

Instrumentation

Perkin Elmer Atomic Absorption Spectrometer A Analyst 400 was used for determination of heavy metals concentration in the samples.

Methods

Study Area

Borno Express, Tashan Kano and Tashan Bama are three motor parks situated within Maiduguri, the Borno state capital in northeastern Nigeria. The city of Maiduguri lies on the coordinate $11^o50'$N $13^o09'$E / 11.833^oN 13.150^oE. These motor parks are characterized by a heavy traffic and passengers.

Sample Collection and Preparation

The soil samples were collected in June, 2019, from three motor parks situated in different parts of the Maiduguri metropolis. These include Borno Express motor park (BOEXP), Tashan Kano motor park (TASKP) and Tashan Bama motor Park (TASBP).

The soil samples were collected at depth of 15 cm around the motor parks, then thoroughly mixed and transferred into clean well-labelled polyethylene bag and transported to the laboratory. The samples were gently homogenized and sieved through 2 mm mesh sieve. The sieved samples were first air dried, then placed in electric oven at an approximate temperature of 40 °C for 30 minutes. The resulting fine powder was stored in clean dry air-tight polyethylene bags and kept at room temperature for onward analysis (Adedeji *et al.*, 2013).

Digestion of Soil Samples

1 g of the oven dried sample was weighed using a top loading balance and placed into 250 ml beakers separately, to which 10 ml of aqua regia (30 % HCl and 70 % high purity HNO_3 in 1:3 ratio) was added. The mixture was then digested at 70 °C till the solution became transparent and evolved brown gas. To the reduced mixture, 5 ml of hydrogen peroxide was added and allowed to reduce to 2 ml through heating. The resulting solution was filtered through Whatman filter paper into a 100 ml volumetric flask and diluted to mark using deionized water. The sample solution was analyzed for concentrations of Cu, Zn, Cd, Cr and Pb using an atomic absorption spectrometer (Abechi *et al.*, 2010).

Pollution Index Models

Contamination Factor (C_f)

The contamination factor is used to ascertain the level of soil contamination by heavy metals. It is defined as the ratio of the concentration of the heavy metal to the background value. It was calculated using equation (1).

$$C_f = C_m/C_b \quad (1)$$

Where, C_m is the concentration of the metal, C_b is the background value. The Department of Petroleum Resources (DPR) target value for heavy metal was taken as the background value (Zn = 95, Cr = 90, Cd = 0.3, Cu = 45, Pb = 20). The standard employed for the interpretation of the contamination factors was that reported by Lacatusu (2000) and adopted from Osakwe (2014). The significance of intervals is presented in Table 2.

Table 1: Background Value from World Average Value in Shale, Target Value and Intervention Values of Metals (mg/kg)

Heavy metals	Background value (b_n)	Target values	Intervention values
Zn	95	140	720
Cr	90	100	380
Cd	0.3	0.8	17
Cu	45	36	190
Pb	20	85	530

Source: DPR (2002) adopted from Edori and Kpee (2017)

Table 2: Significance of Intervals of Contamination/Pollution Index

C/PI Interval	Significance
< 0.1	Very slight contamination
0.10 – 0.25	Slight contamination
0.26 – 0.50	Moderate contamination
0.51 – 0.75	Severe contamination
0.76 – 1.00	Very severe contamination
1.1 – 2.0	Slight pollution
2.1 – 4.0	Moderate pollution
4.1 – 8.0	Severe pollution
8.1 – 16.0	Very severe pollution
> 16.0	Excessive pollution

Source: Edori and Kpee (2017)

Pollution Load Index (PI)

pollution load index is the measure of degree of overall contamination in a sample station. The procedure adopted by (Fosu-mensah *et al.*, 2017) was used to calculate the PI for each site.

$$PI = (Cf_1 \times Cf_2 \times Cf_3 \ldots\ldots\ldots Cf_n)^{1/n} \qquad (2)$$

The PI of each element is classified as thus,

($PI \leq 1$) low, ($1 < PI \leq 3$) moderate, or ($PI > 1$) high

Ecological Risk Factor (Er)

Ecological risk factor is the quantitative expression of potential ecological risk of a given contaminant and is defined as the ratio of the toxic response factor to the contamination factor for a given contaminant or pollutant. It is given by equation (3).

$$Er = Tr \times Cf \qquad (3)$$

Where Tr is the toxic response factor for a given contaminant and C_f is the contamination factor.

Generally,

$Er < 40$ (low potential ecological risk)

$40 \leq Er < 80$ (moderate potential ecological risk)

$80 \leq Er < 160$ (considerable potential ecological risk)

$160 \leq Er < 320$ (high potential ecological risk)

$Er \geq 320$ (very high potential ecological risk)

RESULTS AND DISCUSSION

Analysis of some heavy metals in soil samples from three motor parks viz; Borno Express (BOEXP), Tashan Kano park (TASKP) and Tashan Bama park (TASBP) of Maiduguri, Borno state have been carried out using atomic absorption spectrometer. The results are presented in Table 3. The results showed zinc mean concentration range of 0.09 - 1.18 mg/kg with BOEXP having the highest concentration of 1.18 mg/kg and TASBP least concentration of 0.09 mg/kg. The result is higher than the reported concentration of 0.0385 mg/kg by Oladeji *et al.* (2016) for Ogbomoso motor park; and 18.41 – 27.37 mg/kg for Gombe motor parks in northeastern Nigeria (Magaji *et al.*, 2019). The primary source of Zn could probably be the attrition of motor vehicle tyre exacerbated by poor road surfaces and the lubricating oils, which contain zinc dithiophosphate as major additive (Abechi *et al.*, 2010). However, the observed values are within the WHO Permissible limit.

Copper levels in the soil samples ranged from 0.18 – 0.19 mg/kg. These concentrations are lower than mean value of 0.482 mg/kg reported in a study conducted in some motor parks in Delta state, Nigeria (Osakwe, 2013) and other places (Oguntimehin and Ipinmoroti, 2007). Presence of copper could be ascribed to the wearing of metal bearings and babbit metal bushings. It has been reported that improperly discarded oils which leaches into the soil contain high proportion of copper as well as lead and antimony (Osakwe, 2013).

The mean concentration of 0.13 mg/kg reported in a work carried out by Osakwe (2013) is in agreement with the level of chromium obtained in the present study (0.08 – 015 mg/kg). similarly, a concentration range of 0.06 – 0.11 mg/kg for Cr in Gombe motor parks have been recorded (Magaji *et al.*, 2019). Pistol rings of automobile and seals could likely be a source of chromium to the soils. Chromium compounds are carcinogenic and causes gastrointestinal hemorrhage, hemolysis and acute renal failure.

The mean concentrations of Cd ranged between 0.18 – 0.19 mg/kg in the soil samples of the three motor parks under consideration. Nevertheless, the levels of all the heavy metals are lower than the concentrations previously reported by Dauda and Odoh (2012) for Otukpo, Makurdi and Gboko motor parks in Benue State of Nigeria. Maximum concentration of Cd (10.2 mg/kg) was recorded in a recent study conducted on a motor park in Ijebu-Ode, Nigeria (Adedeji *et al.*, 2019). However, an observable similitude is apparent from the concentration range of 0.17 – 0.22 mg/kg reported in a research carried out on motor parks soils in Asadabad, Iran (Solgi, 2016). Interestingly, the levels are all within the allowable limits set by WHO. Cadmium can cause kidney lesions, hypertension, mutagenesis and carcinogenesis. The most important adverse effect of cadmium in human is Itai-Itai disease which affects calcium and bone metabolism and was first reported in Japan (Mohammed *et al.*, 2020).

The results of the analysis as shown in table 3 for the selected areas proves that the content of heavy metals in the soils was restricted to top soil 0 – 15 cm depth. Previous studies show that the surface soil is better indicator of metallic burden (Oyewale and Funtua, 2002). The relative low concentrations observed could be due to low agricultural activities, automobile emission and lack of heavy wind disperses around the sites.

Table 3: Mean Concentration (mg/kg) of Heavy Metals in Soil Samples of Motor Parks

Motor Park	**Concentration (mg/kg)**				
	Zn	**Cr**	**Cd**	**Cu**	**Pb**
BOEXP	1.18	0.15	0.07	0.29	N/D
TASKP	0.09	0.08	0.18	0.19	N/D
TASBP	0.34	0.04	0.41	0.18	N/D
WHO LIMIT	10	1.0	0.01	2.0	2.0

N/D = Not detected

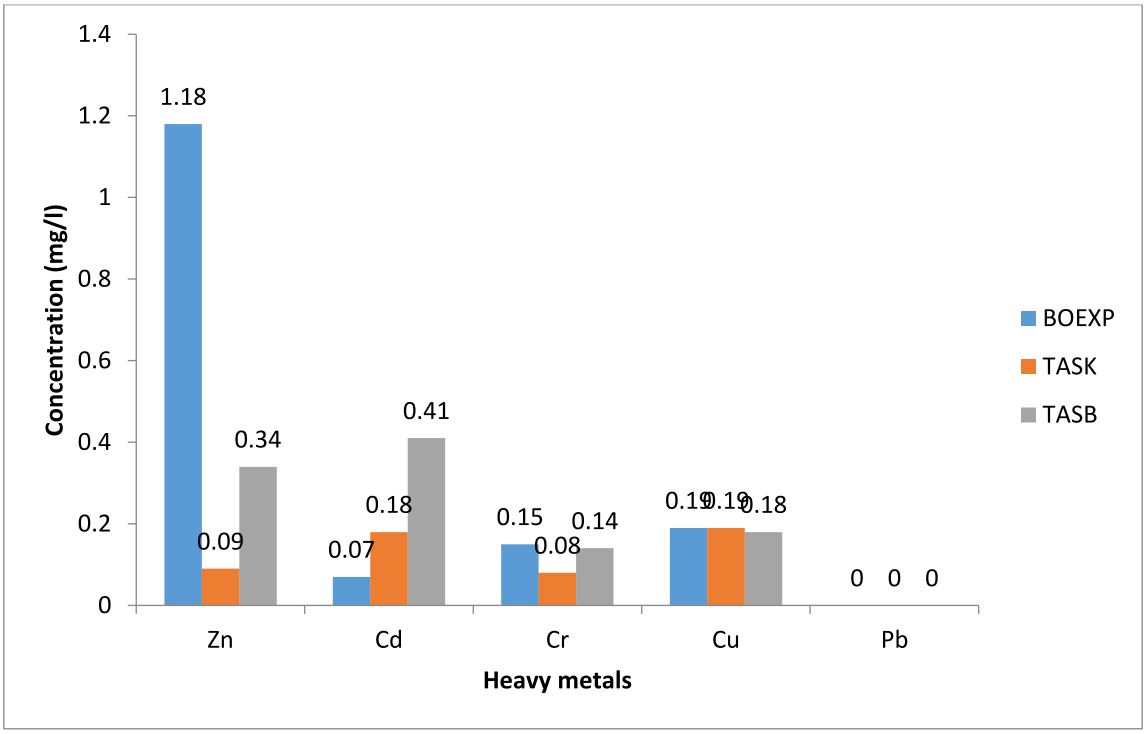

Figure. 1: Comparison of Mean concentrations of heavy metals in soils of the motor parks

Contamination Factor and Pollution Load Index

Table 4 shows the results of the calculated contamination factors and pollution load index of the heavy metals under study in the sampled soils of the motor parks. Applying the classification earlier reported by Fosu-mensah *et al.* (2017) to interpret the PI data, the pollution load index for the individual metal fell within the low contamination (PI ≤ 1) for all the heavy metals analyzed in the soil samples of the three motor parks (Pradhan and Kumar, 2014). This implies that the presence of these heavy metals in the earth crust was low and their pollution in the soil is very minimal. However, comparison of the contamination factor and pollution index load with the categorization of significance of interval reported by Lacatusu (2000) revealed that all the heavy metals analyzed except cadmium, showed contamination factor as well as pollution index value < 0.1 indicative of very slight contamination. Furthermore, the contamination factor of cadmium in the TASKP fell within the slightly contaminated category (0.10 – 0.25) whereas in TASBP with a of 0.5125 fell within the category (0.51 -0.75) implying severe contamination.

Table 4: Contamination Factor (C_f) and Pollution Index (PI) for Heavy Metals in Soils from Motor Parks

Motor Park	Contamination factor (C_f)					Pollution Index (PI)
	Zn	Cr	Cd	Cu	Pb	
BOEXP	0.00843	0.0015	0.0875	0.00806	N/A	0.0097177
TASKP	0.00064	0.0008	0.2250	0.00528	N/A	0.0049662
TASBP	0.00243	0.0004	0.5125	0.00500	N/A	0.0070645

N/A: Not applicable

Ecological risk factor

The metal with the highest ecological risk factor was copper with Er of 2.625, 6.75 and 15.375 for BOEXP, TASKP and TASBP motor parks respectively. Comparing with the categorization previously adopted and reported by Edori and Kpee (2017), the Er values of the studied heavy metals in the soil samples of the motor parks fall within the low potential ecological risk category (Er < 40). The results are presented in table 5.

Table 5: Ecological Risk Factor (Er) of Heavy Metals for Motor Parks

Heavy Metals	***Tr***	***Ecological Risk Factor (Er)***		
		BOEXP	**TASKP**	**TASBP**
Zn	1	0.00843	0.00064	0.00243
Cr	2	0.00300	0.00160	0.00080
Cd	30	2.625000	6.75000	15.3750
Cu	5	0.040300	0.02640	0.02500
Pb	5	N/A	N/A	N/A

Tr : Toxic response factor, N/A: Not applicable

CONCLUSION

The levels of heavy metals in soils of three motor parks in Maiduguri, Borno state, Nigeria were determined. The results showed the order in concentrations as follows: Zn > Cu > Cr > Cd for Borno Express motor park (BOEXP), Cu > Cd > Zn > Cr for Tashan Kano motor park (TASKP) and Cd > Zn > Cu > Cr for Tashan Bama motor park (TASBP). The relative pollution potentials of the metals showed that the soils were contaminated with different degrees of contaminations. The contamination/pollution load indices confirmed slight and severe contamination for cadmium in soils of TASKP and TASBP motor parks respectively. However, the other metals (Zn, Cr, and Cu) revealed very slight contaminations of the soils studied. In general, the contamination levels of the soils by the heavy metals could be considered to have no serious implication as at the time of the study.

Conflict of Interest Statement

No conflict of interest exists among authors.

References

Abechi, E. S., Okunola, O. J., Zubairu, S. M. J., Usman, A. A., & Apene, A. (2010). Evaluation of Heavy Metals in Roadside Soils of Major Streets in Jos Metropolis, Nigeria. *Journal of Environmental Chemistry and Ecotoxicology*, *2*(6), 98-102.

Adedeji, O. H., Olayinka, O. O., & Oyebanji, F. F. (2013). Assessment of Traffic Related Heavy Metals Pollution of Roadside Soils in Emerging Urban Centres in Ijebu-North Area of Ogun State, Nigeria. *Journal of Applied Sciences and Environmental Management*, *17*(4), 509-514.

Adedeji, O. H., Olayinka, O. O., & Tope-Ajayi, O. O. (2019). Spatial Distribution and Health Risk Assessment of Soil Pollution by Heavy Metals in Ijebu-Ode, Nigeria. *Journal of Health and Pollution, 9*(22), 1-14.

Dauda, M. S., & Odoh, R. (2012). Impact of Motor Parks on the Concentration of Heavy Metals in Some Selected Urban Areas of Benue State, Nigeria. *Der Chemica Sinica*, *3*(3), 745-752.

Diskshith, T. S. S., & Diwan, P. V. (2003). *Industrial Guide to Chemical and Drug Safety*. Wiley: New York.

DPR. (Department of petroleum Resources) (2002). Environmental Guidelines and Standards for the Petroleum Industry in Nigeria (Revised Edition). Department of Petroleum Resources, Ministry of Petroleum and Mineral Resources.

Edori, O. S., & Kpee, F. (2017). Index Models Assessment of Heavy Metals Pollution in Soils within Selected Abbatoirs in Port Harcourt, Rivers State, Nigeria. *Singapore Journal of Scientific Research*, *7*(1), 9-15.

Fasu-Mensah, B. Y., Okoffo, E. D., Darko, G., & Gardon, C. (2016). Assessment of Organochlorine Pesticide Residues in Soils and Drinking Water Sources from Cocoa Farm in Ghana. *Springerplus*, *5*(869).

Fifield, F. W., & Haines, P. J. (2002). *Environmental Analytical Chemistry* (2nd Edn.), Blackwell Science Ltd.

Lacatusu, R. (2000). Appraisal Levels of Soil Contamination and Pollution with Heavy Metals. In: Land Information Systems for Planning the Sustainable Use of Land Resources, Heinike, H. J., Eckselman, W., Thonsasson, A. J., Jones, R. J. A., Montanorella, L. and Buckeley, B. (Eds). Office of Official Publication of the European Communities, Luxembourg, pp. 393-402.

Magaji, B., Danbature, W. L., Shehu, Z., Sani, M. M., Sani, A. M., & Abubakar, A. (2019). Evaluation of Some Heavy Metals in Soils Around Major Parks in Gombe Town Nigeria. *Asian Journal of Applied Chemistry Research*, *4*(4), 1-5.

Mohammed, A. I., Ahmed, A. A., & Dauda, E. T. (2020). Determination of Levels of Heavy Metals and Physicochemical Parameters in Waste Water of Kasuwan shanu Abattoir, Maiduguri. *Journal of Chemistry Letters*, *1*(3), 84-88.

Oguntimehin, S. O., & Ipinmoroti, K. (2007). Profile of Heavy metals from Automobile Workshops in Akure, Nigeria. *Journal of Environmental Science and Technology*, 1-8.

Oladeji, J. T., Adetola, S. O., & Ogunsola, A. D. (2016). Heavy Metal Concentrations in Soil of Ogbomoso and its Environs, *Merit Journal of Environmental Science and Toxicology, 4*(1), 001-005.

Osakwe, S. A. (2013). Pollution Status of Soils and Vegetation Around Busy Motor Parks in Selected Areas of Delta State, Nigeria. *IOSR Journal of Applied Chemistry, 4*(2), 05-12.

Osakwe, S. A. (2014). Heavy Metal Contamination and Physicochemical Characteristics of Soils from Automobile Workshops in Abbaka, Delta State, Nigeria. *International Journal of Natural Sciences Research*, *2*(4), 48-58.

Oyeleke, P. O., Abiodun, O. A., Salako, R. A., Odeyemi, O. E., & Abejide, T. B. (2016). Assessment of Some Heavy Metals in the Surrounding Soils of an Automobile Battery

Factory in Ibadan, Nigeria. *African Journal of Environmental Science and Technology*, *10*(1), 1-8.

Oyewale, O. A., & Funtua, I. I. (2002). Lead, Copper, Zinc Levels in Soils along Kaduna-Zaria High way, Nigeria. *Global Journal of Environmental Sciences*, *1*, 7-13.

Pradhan, J. K., & Kumar, S. (2014). Informal e-wste Recycling: Environmental Risk Assessment of Heavy Metal Contamination in Mandoli Industrial Area, Delhi, India. *Environmental Science and Pollution Research, 21*(13), 7913-7928.

Salt, D. E., Blaylock, M., Kumar, N. P. B. A., Duschenkov, B., Ensley, B., Chet, I., & Raskin, I. (1995). Phytoremedation: A Novel Strategy for Removal of Toxic Metals from the Environments Using Plants. *Journal of Biotechnology*, *13*, 468-474.

Solgi, E. (2016). Contamination of Two Heavy metals in Topsoils of the Urban Parks Asadabad, Iran 2013. *Archives of Hygiene Sciences*, *5*(2), 92-101.

Sulaiman, M. B., Santuraki, A. H. and Babayo, A. U. (2018). Ecological Risk Assessment of Some Heavy Metals in Roadside Soils at Traffic Circles in Gombe, Northern Nigeria. *Journal of Applied Science and Environmental Management, 22*(6), 999-1003.

Waldron, H. A. (1980). *Metals in the Environment*. London, England: Academic Press.