PATTERN OF DISTRIBUTION AND CONCENTRATION OF SELECTED HEAVY METALS IN FARMLANDS NEAR ROADSIDES IN OWERRI, NIGERIA

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Abstract. Vehicular traffic has been implicated in increasing heavy metals concentrations in nearby soils. Notably, severe environmental and health challenges have been associated with elevated concentrations of these heavy metals, hence the need to monitor them in adjoining farmlands to forestall entry into food chains. The distribution patterns of Pb, Cd, Mn and Cu on Owerri-Onitsha and Owerri-Aba expressways were studied. Soil and *Panicum maximum* leaf samples were collected at 3 locations on each road at 5m, 10m and 15m away from the roadsides. Samples were processed and analysis for heavy metal concentrations was done with atomic absorption spectrophotometer (AAS). Results obtained indicated the presence of all the selected heavy metals at almost all the locations and points studied. The order for heavy metals in samples from Owerri-Aba expressway was Pb>Cu>Cd>Mn, while that of Owerri-Onitsha was Mn>Pb>Cu>Cd. Although the concentrations generally fluctuated with increasing distance away from the roadsides at most locations, in some grass samples it increased with distance. There was also a decline in their concentrations with increasing distance away from the road for some soil samples. Owerri-Onitsha expressway gave higher concentrations of heavy metals in both samples than Owerri-Aba expressway. Meanwhile, the concentrations of Mn and Cu in plant extracts were generally below the maximum allowable levels while Pb and Cd far exceeded it. Similarly, their concentrations in soil samples were below the EU limits except Cd. Results of metal bioaccumulation factor revealed that *Panicum maximum* moderately bioaccumulated most heavy metals from the soil. There was weak or no correlation between heavy metal contents of soil and *P. maximum* samples. Atmospheric deposition also contributed to the heavy metals in plant samples. Since some heavy metals studied exceeded their recommended limits, it is advisable to discourage farming activities upto 15m from the roadsides, especially on sloped roadsides.

Keywords: exhaust fumes; roadside; heavy metals; bioaccumulation; distribution; Owerri-Aba road; Owerri-Onitsha road.

INTRODUCTION

Although heavy metals occur naturally at different concentrations in the ecosystem, several anthropogenic sources including mining, exploration and combustion of petroleum products have increased their concentration in every component of the ecosystem [18]. Soil is one of the highest receivers of these heavy metals. Increase in the concentration of heavy metals in the environment poses great ecological and health concern. This is in view of their translocation through food chains, toxicity at certain concentrations and non-biodegradability which is leads to their bioaccumulation in the biosphere [6, 14]. Studies have shown that soil contamination by heavy metals like Pb, Cu, Cd, Zn and Ni has led to concomitant increase in bioaccumulation of these heavy metals in plants and forage grasses [8].

Other anthropogenic activities that contribute to heavy metals pollution are smelting, manufacturing, application of fertilizers and pesticides in farms, municipal waste, vehicular emissions, and industrial effluents [8, 15, 27]. Translocation of heavy metals through irrigation and growth of plants on such contaminated soil leads to contamination of food which may be hazardous to humans and animals [11]. Some heavy metals like copper and zinc which may be bio-essential at minute quantities, may cause physiological and ecological problems if present at certain higher concentrations [14]. Ingestion of excessive concentrations of these metals may cause cancer, nervous system damage, cumulative poisoning and ultimately death in humans [14].

Interestingly, previous studies have reported the capabilities of different plants to bioaccumulate heavy metals when grown on polluted soils. In their studies, Sulyman [24] found that rice, maize, millet, guinea corn, and wheat contained varying concentrations of Cu, Zn and Fe. Heavy metals were also detected from samples of spinach, cabbage and radish cultivated on polluted soil [17]. A study conducted in Yucheng City, China, showed an increase of Ni, As, Hg and Pb concentrations in wheat and corn samples as well as Cd in wheat samples [12] and in maize in Tongliao, China [32].

On the other hand, *Panicum maximum* (Guinea grass) is a perennial grass which robustly grows up to 3.5 m in height [3]. In both the tropical and subtropical regions, guinea grass remains a major forage grass for ruminants. At its tender stage, it is a very palatable fodder upon which ruminant livestock feed. However, the nutritional value tends to reduce with age. Moreover, it is capable of growing on a wide range of soil conditions and performs well in area receiving 800 – 1800 mm annual rainfall and with a dry season of less than 4 months. The grass easily dies if overgrazed and in dry season [21]. Guinea grass is a member of the family *Poaceae.* The subfamily is *Panicoideae*, while the tribe is *Paniceae. P. infestum, P. anders* and *P. trichocladum* are other agamic complexes of *P. maximum*. However, *Panicum maximum* has very few identified sexual accessions [15]. Guinea grass is known to for its persistent, good yield and high quality in both tropical and sub-tropical regions. It is thought that guinea grass originated from Africa in which it is most diverse [15]. In the entire South Eastern Nigeria, this grass grows profusely during rainy season, including on the roadsides.

This study evaluated the total concentrations and pattern of distribution of selected heavy metals in extracts of guinea grass (*Panicum maximum*) and soil samples collected between 5 – 15m away from roadsides of two expressways in Owerri, Nigeria. This is with a view to providing information necessary to check the entry of heavy metals into food chain.

MATERIALS AND METHODS

Study area

The samples used in this study were randomly collected at selected locations at the Imo State sections of Owerri – Onitsha road and Owerri – Aba road, both of which are trunk A category roads. The soil at the locations studied is laomy in nature. The edge of the roads are not paved and the roads sloped off on both sides into the adjoining farmlands. There are no tree covers but grasses.

Samples collection and preparation

At each location studied, samples of guinea grass leaves were collected at 5 m, 10 m and 15 m away from the main road. Similarly, using well cleaned soil auger, soil samples on which the grasses were growing were collected at depth of 0.30m at same points where grass samples were obtained. Each sample was carefully packaged in cleaned polythene bags and then labeled accordingly. The samples were sent to the laboratory for processing and evaluation.

The collected leaves were cut into smaller pieces, completely air dried and ground to powder with thoroughly cleaned pestle and mortar. Soil samples were pulverized to fine particles, air dried and sieved in a sieve shaker of particle size 1 mm. The pulverized samples were then packaged in air tight container till analyzed.

Digestion of soil and leaf samples and measurment of heavy metal concentrations

The modified method of [4] was used. With a weighing balance, 1gram of each of the dried samples of soil was put into a porcelain crucible and muffle furnace was used to dry-ashed them. This was done by stepwisely increasing the temperature to 500°C within an hour and allowing them to ash at the temperature for another 12 h. Complete dissolution of the resulting residue was done in 1M HNO_3. They were filtered with Whatman No 42 filter paper into a 25 mL volumetric flask then made up to mark with 1M HNO_3. The leaf samples were processed by wet digestion with a mixture 0.0125M HNO_3: 0.05M HCl (3:1) as earlier described by [4] with modifications. Each leaf sample (1 g) was digested with 20ml of the acid mixture and then heated to 150°C for 2½ h on a heating digestion block. The digest was allowed to cool and filtered with Whatman No 42 filter paper into a 25 mL volumetric flask which was made up with de-ionized water.

The heavy metal concentrations of the samples were determined with Flame Atomic Absorption Spectrophotometer (FAAS) technique using air-acetylene flame and hollow cathode lamps (HCL) as light sources. Appropriate wavelengths (nm) (Cu = 324.8; Pb = 217.0; Mn = 279.5 and Cd = 228.8), slit (nm) (0.5 for Cu; 1.0 for Pb; 0.5 for Mn and 0.5 for Cd) and lamp current (mA) were selected. All reagents used were of analytical grade. Standard stock solutions of metals (1.0000 mg/dm^3 as nitrate salts in 0.5 mol/dm^3 nitric acid) were prepared by appropriate dilution of stock standards with deionized water. The digested samples were in turn put to AAS and readings obtained.

RESULTS

Leaf extracts of *Panicum maximum* and soil samples collected at 5m, 10m and 15m away from roadsides of Owerri – Aba and Owerri - Onitsha expressways were analyzed for cadmium (Cd), copper (Cu), manganese (Mn) and lead (Pb).

Concentration of selected heavy metals in leaf extracts of *Panicum maximum* from Owerri-Aba expressway

All the selected heavy metals studied were present in the samples collected at all the distances except for Mn at 5m (location 1) and 15m (location 3), Pb at 15m (location 3) and Cu at 10m (location 3) respectively. It was observed that concentrations (mg/kg) of the heavy metals fluctuated with distance away from the roadside. Lead showed highest concentration at all the locations while Mn was the least. Pb and Mn consistently increased with distance from the road while Cu maintained an initial decrease at 10m but later increased at 15m from the road. The results obtained are shown in figures 1-3.

Concentration of selected heavy metals in soil samples from Owerri-Aba expressway

Similarly, the heavy metals were detected in all the soil samples studied except Cu (location 2) and at 15m (location1) as well as Pb at 10m (location 1) respectively. However, unlike the results from leaf extracts of *P. maximum,* the concentrations of heavy metals in the soil samples generally decreased with distance away from the road. Lead had highest concentration, while manganese was least. The results are shown in figures 4-6.

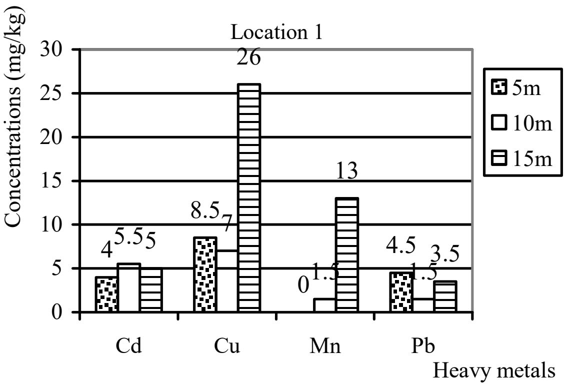

Figure 1. Concentratifons of heavy metals in leaf extracts of *P. maximum* at location 1 on Owerri-Aba expressway

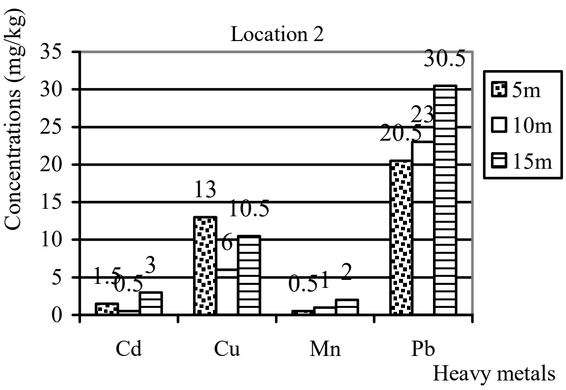

Figure 2. Concentratifons of heavy metals in leaf extracts of *P. maximum* at location 2 on Owerri-Aba expressway

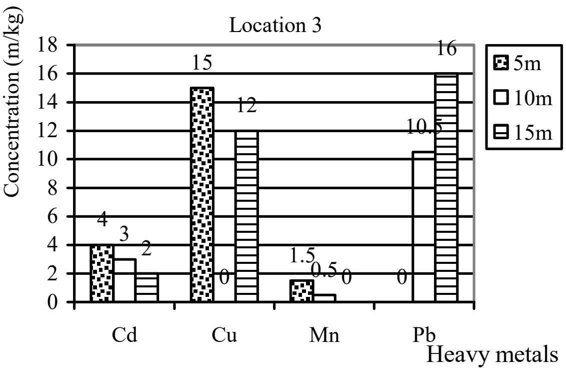

Figure 3. Concentratifons of heavy metals in leaf extracts of *P. maximum* at location 3 on Owerri-Aba expressway

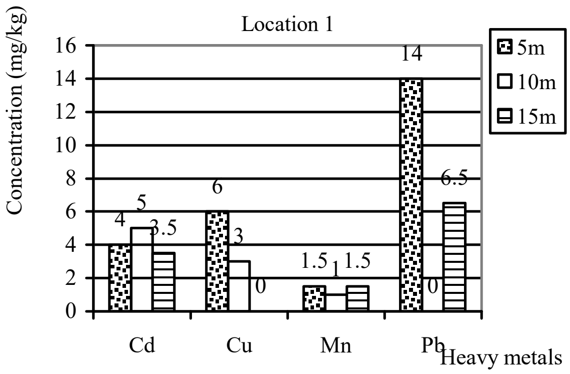

Figure 4. Concentrations of heavy metals in soil samples at location 1 on Owerri-Aba expressway

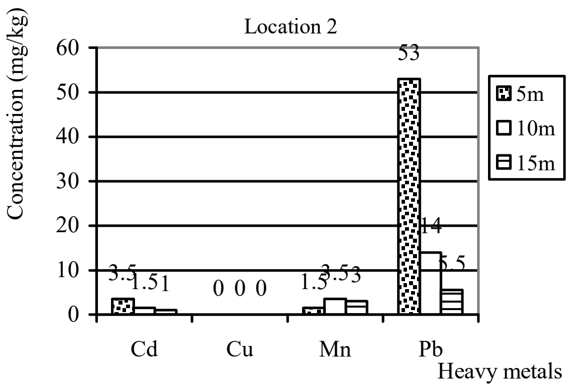

Figure 5. Concentrations of heavy metals in soil samples at location 2 on Owerri-Aba expressway

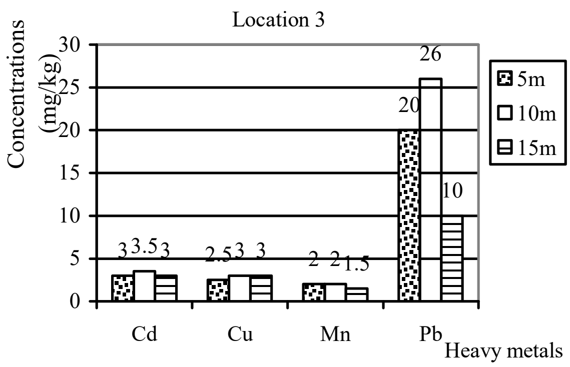

Figure 6. Concentrations of heavy metals in soil samples at location 3 on Owerri-Aba expressway

Concentration of selected heavy metals in leaf extracts of *Panicum maximum* from Owerri-Onitsha expressway

The concentration of heavy metals in *P. maximum* samples from Owerri-Onitsha expressway was higher than those from Owerri-Aba expressway. Moreover, they were detected in all the samples studied. At locations 2 and 3, the concentrations of the heavy metals increased with distance from the road. The reverse was the case at location 1. Manganese was the highest while Cadmium the least. Figures 7-9 show the results obtained.

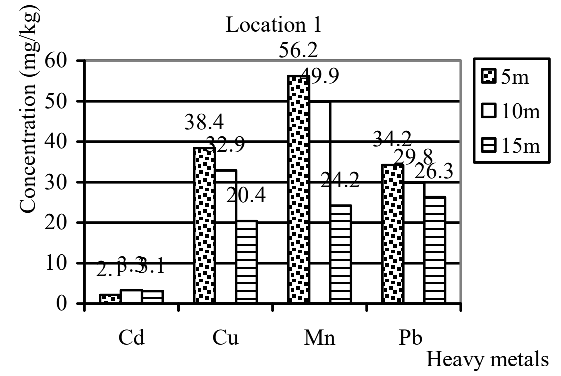

Figure 7. Concentrations of heavy metals in leaf extracts of *P. maximum* at location 1 on Owerri-Onitsha expressway

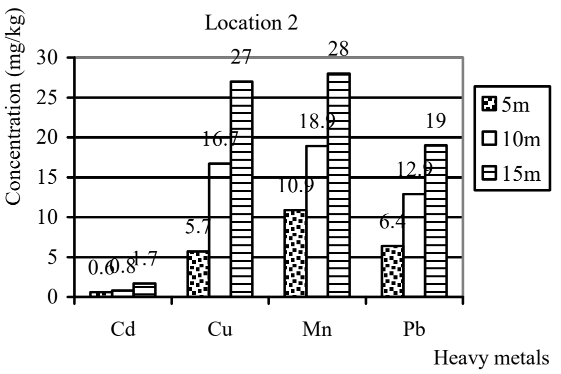

Figure 8. Concentrations of heavy metals in leaf extracts of *P. maximum* at location 2 on Owerri-Onitsha expressway

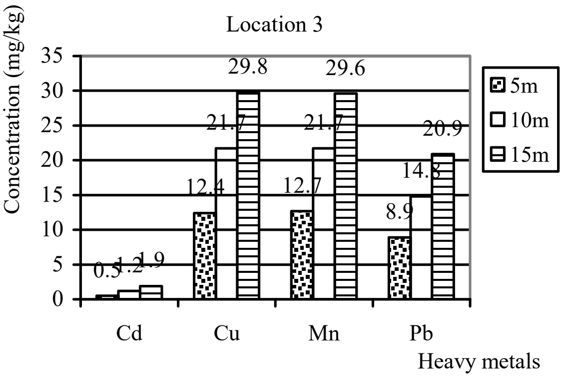

Figure 9. Concentrations of heavy metals in leaf extracts of *P. maximum* at location 3 on Owerri-Onitsha expressway

Concentration of selected heavy metals in soil samples from Owerri-Onitsha expressway

Likewise, all the studied heavy metals were present in the soil samples from Owerri-Onitsha expressway at concentrations higher than those from Owerri-Aba expressway. Manganese had the highest concentration and the Cadmium, the least detected. Similar to results obtained from leaf extract, the concentrations of the heavy metals increased with increase in distance from the road at locations 2and 3, but decreased with it at location 1. Details of the results obtained are shown in figures 10-12.

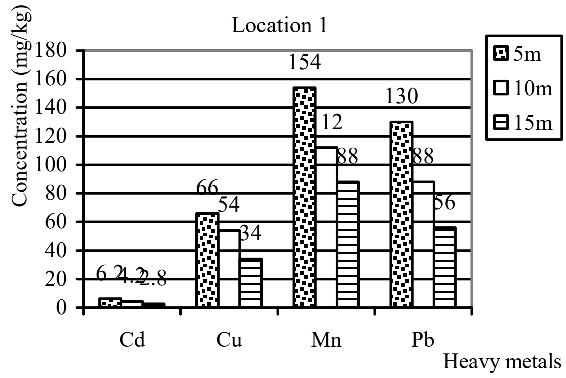

Figure 10. Concentrations of heavy metals in soil samples at location 1 on Owerri-Onitsha expressway

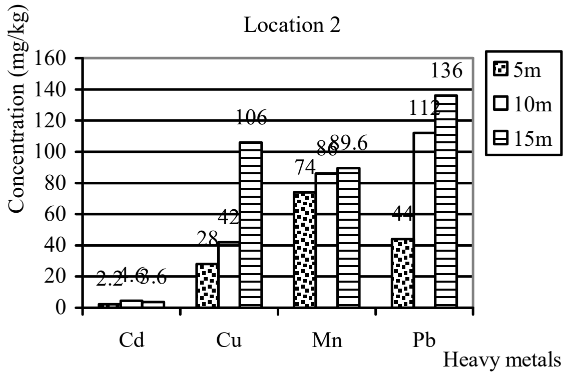

Figure 11. Concentrations of heavy metals in soil samples at location 2 on Owerri-Onitsha expressway

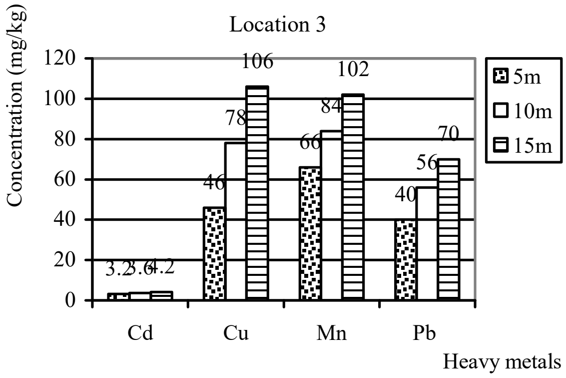

Figure 12. Concentrations of heavy metals in soil samples at location 3 on Owerri-Onitsha expressway

Concentration of heavy metals at various distances

Although the concentrations of heavy metals from both soil and *P. maximum* samples from the two expressways studied generally fluctuated with increasing distance as shown in figures 1-12, in most cases, the concentrations increased with increasing distance from the roads except for soil samples from Owerri-Onitsha road. However, on statistical analysis of the samples with one-way ANOVA, there was no significant difference in the concentrations of the heavy metals between distances 5m, 10m and 10m respectively.

Metal bioaccumulation factor (BAF)

BAF is an indicator of the potentials of plants to bioaccumulate heavy metals from soil. Plants with BAF value of 1 and above are heavy metals bioaccumulator and as such dangerous for food or fodder. Using equation 1, heavy metal bioaccumulation factor of *P. maximum* was calculated per dry weight of plant sample and results are shown in tables 1 and 2. Generally, *Panicum maximum* did not bioaccumulate any of the heavy metals studied except at some points from Owerri-Aba expressway.

$$BAF = \frac{Concetration\ of\ heavy\ metal\ in\ plant}{Concentration\ of\ heavy\ metal\ in\ soil}$$

(equ.1) [20, 22]

Table 1. Heavy metals bioaccumulation factor for *P. maximum* collected at various distances from roadside of Owerri-Aba expressway, Nigeria

Location	Sample	Bioaccumulation Factor (BAF)			
		Cd	Cu	Mn	Pb
1	5m	1.0	1.4	0.0	0.3
	10m	1.1	2.3	1.5	0.0
	15m	1.4	0.0	8.7	0.5
2	5m	0.4	0.0	0.3	0.4
	10m	0.3	0.0	0.3	1.6
	15m	3.0	0.0	0.7	5.5
3	5m	1.3	9.2	0.8	0.0
	10m	0.9	0.0	0.3	0.4
	15m	0.7	4.0	0.0	1.6

Table 2. Heavy metals bioaccumulation factor for *P. maximum* collected at various distances from roadside of Owerri-Onitsha expressway, Nigeria

Location	Sample	Bioaccumulation factor (BAF)			
		Cd	Cu	Mn	Pb
1	5m	0.7	0.8	0.9	0.9
	10m	0.9	0.4	0.6	0.5
	15m	0.7	0.2	0.2	0.4
2	5m	0.3	0.2	0.1	0.1
	10m	0.2	0.4	0.2	0.1
	15m	0.5	0.3	0.3	0.1
3	5m	0.1	0.2	0.1	0.1
	10m	0.3	0.4	0.2	0.2
	15m	0.7	0.9	0.3	0.4

Correlation between heavy metals in soil and *P. maximum*

The results of Pearson correlation coefficient ($p < 0.05$) showed that on Owerri-Aba expressway, Cd and Pd in *P. maximum* had weak correlation while Cu and Mn had no correlation with those in the soil samples collected. On Owerri-Onitsha expressway, only Cu in *P. maximum* showed weak correlation, while others had no correlation with soil samples. This could account for the high values of BAF recorded at some points for Cu and Mn in samples from Owerri-Aba expressway.

DISCUSSION

Variation in concentration of heavy metals in samples

Results of this study revealed that all the selected heavy metals were present in both soil and plant samples at locations 1, 2 and 3 of Owerri-Aba and Owerri-Onitsha express ways. This finding is supported by separate reports of [18, 22, 26-28]. Anthropogenic factor such as discharge of untreated effluents of refinery and petrochemical industries into nearby soil had earlier been implicated as a caused of heavy metal pollution [5] as well as exhaust fumes [25, 31]. In both soil and plant samples collected from Owerri-Aba expressway, the results obtained indicated that Pb>Cu>Cd>Mn. Amadi [5] had similarly reported the detection of heavy metals in soil near refinery in the order Fe>As>Zn>Cu>Pb>Cr>Cd>Mn and Zn>Pb>Fe>Cu>Mn>Cd>Cr on roadside soils [5]. This finding is also in line with the report of [22] which showed Cu>Cr>Co>Pd>Cd in soil sample.

On the other hand, the sequence of concentrations of heavy metals in both samples from Owerri-Onitsha expressway was Mn>Pb>Cu>Cd. This corroborates the results reported by [16], which was in the order Mn>Fe>Zn>Cu>Cd. Samples from Owerri-Onitsha expressway yielded higher concentrations of heavy metals than those from Owerri-Aba expressway. Different concentrations of same heavy metals on different roads have been reported [1] and are correlated to the volume of traffic [2]. Since there is no industry cited close to any of the locations of sample collection on both expressways, it is most likely that the heavy metals were from exhaust fumes from vehicles plying the roads. Also, the higher traffic normally witnessed on Owerri-Onitsha expressway further implicates vehicular exhaust fumes as the source of most of the heavy metals [2]. Wang [27] and Abdulrashid [1] attributed heavy metal pollution of urban and roadside soils mainly to commercial activities, petrochemical industry, traffic, chemical industry and coal. The concentrations of Mn and Cu in plant extracts were generally below the maximum allowable levels while Pb and Cd far exceeded the limits by CERSPC, as cited in [23]. Similarly, the concentrations of Pd, Mn and Cu in soil were below the limits of 300 mg/kg, 2000mg/kg and 140mg/kg respectively, while that of Cd is higher than 3.0 mg/kg maximum limit by [9, 10].

Concentration of heavy metals at various distances

The report of [31] corroborates the findings in this study that the concentrations of the heavy metals at most of the locations fluctuated with increasing distance from the roadsides. Although there was no significant difference between their concentrations, at most locations studied, the concentrations of heavy metals however increased with increasing distance from the expressways. This finding is not in line with the reports of [7, 31], which showed decrease in concentration with increasing distance from the roadsides. The landscape of a location may affect the distribution of heavy metals away from the road because runoff would deposit more heavy metals away from sloppy roadsides. Moreover, there is a report that higher concentrations of heavy metals were detected in soil samples down wind direction [7]. As reported by [31], absence of tree covers at all the sampled sites which may serve as protection to the grasses and soil could have affected the results. Regular farming activities such as plough, fertilization as well as irrigation may enhance the mixing of top soil in the farmland and disturbance of the heavy metal distance-distribution pattern on the roadsides [31]. Therefore, higher soil pH and organic matter content would retain more heavy metals near roadsides thus reducing their erosion to farther distances [28].

Metal bioaccumulation factor (BAF) correlation between heavy metals in soil and *P. maximum*

Although bioaccumulation factor determined in this study generally revealed that *Panicum maximum* relatively bioaccumulated some heavy metals from the soil. This supports the findings of [13, 26]. It may be that *P. maximum* has high phytovolatilization potential [18, 22]. This makes it suitable as fodder for feeding livestock [22, 23]. This is buttressed by the weak or no correlation coefficients recorded between the heavy metal contents of soil and *P. maximum* samples. Electrolytes in soil also affect heavy metals bioaccumulation, as well as their transformation [20]. Moreover, the lack of significant correlation further explains that aerial deposition of polluted air from vehicular exhaust fumes may have contributed to the presence of these heavy metals in the plant samples. Amadi [5] had earlier associated the presence of similar heavy metals to pollution by petroleum products. Other sources from vehicles include brake wear, lubricating oil consumption, road abrasion, tire wear etc [29, 30].

REFERENCES

[1] Abdulrashid, L., Yaro, A., Yaro, A., (2017): Heavy metals concentration in roadside soil in Katsina City. Dutse Journal of Pure and Applied Sciences, 3(1): 407-421.

[2] 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 Science and Environmental Management, 17(4): 509-514.

[3] Aganga, A.A., Tshwenyane, S., (2004): Potential of guinea grass (*Panicum maximum*) as forage crop in livestock production. Pakistan Journal of Nutrition, 3(1): 1-4.

[4] Akinyele, I.O., Shokunbi, O.S., (2015): Comparative analysis of dry ashing and wet digestion methods for the determination of trace and heavy metals in food samples. Food Chemistry, 173: 682-684.

[5] Amadi, A.N., Okoye, N.O., Alabi, A.D., Tukur, A., Angwa, E.M., (2014): Quality assessment of soil and groundwater near Kaduna Refinery and Petrochemical Company, Northwest Nigeria. Journal of Scientific Research and Reports, 3(6): 884-893.

[6] Awololu, O.R., (2005): Environmental monitoring and assessment. Leyte Publishers, Baybay, Philippines, pp. 31-447.

[7] Chen, X., Xia, X., Zhao, Y., Zhang, P., (2010): Heavy metal concentrations in roadside soils and correlation with urban traffic in Beijing, China. Journal of Hazardous Materials, 181: 640-646.

[8] Chibuike, G.U., Obiora, S.C., (2014): Heavy metal polluted soils: Effect on plants and bioremediation methods. Applied Environmental Soil Science, 4(12): 23-32.

[9] European Union (2006): Commission decision of 03/XI/2006: Limitations of hazardous substances. http://ec.europa.eu/transparency/regdoc/rep/3/2006/EN/3-2006-5369-EN-1-0.Pdf. Retrieved, 06 October, 2019, 7 p.

[10] FEPA, (1997): Guidelines and standard for environmental impact assessment in Nigeria. pp. 87-95.

[11] Jolly, Y.N., Islam, A., Akbar, S., (2013): Transfer of metals from soil to vegetables and possible health risk assessment. Springer Plus, 2: 1–8.

[12] Lin, J., Wuyi, W., Yonghua, L., Linsheng, Y., (2010): Heavy metals in soil and crops of an intensively farmed area: A case study in Yucheng City, Shandong Province, China. International Journal of Environmental Research in Public Health, 7: 395-412.

[13] Mbong, E.O., Akpan, E.E., Osu, S.R., (2014): Soil-plant heavy metal relations and transfer factor index of habitats densely distributed with *Citrus reticulata* (tangerine). Journal of Research in Environmental Science and Toxicology, 3(4): 61-65.

[14] Morgan, R., (2013): Soil, heavy metals, and human health. pp. 59-82. In Brevik, E.C., Burgess, L.C., (eds): Soils and human health. CRC Press, Boca Raton, FL, USA.

[15] Muir, J.P., Jank, L., (2004): Guinea grass. 45: 589-621. In Moser, L. E., Burson B., Sollenberger L. E., (eds): Warm-season: Grasses. American Society of Agronomy Press.

[16] Nanven, N.D., Egila, J.N., Lohdip, Y.N., (2015): Heavy metal concentrations in some vegetables grown in a farm treated with urban solid waste in Kuru Jantar, Nigeria. British Journal of Applied Science & Technology, 8(2): 139-147.

[17] Nimyel, D. N., Egila, J. N., Lohdip, Y. N. (2015): Heavy metal concentrations in some vegetables grown in a farm treated with urban solid waste in Kuru Jantar, Nigeria. British Journal of Applied Science & Technology, 8(2): 139-147.

[18] Olatunji, O.S., Ximba, B.J., Fatoki, O.S., Opeolu, B.O., (2014): Assessment of the phytoremediation potential of *Panicum maximum* (guinea grass) for selected heavy metal removal from contaminated soil. African Journal of Biotechnology, 13(19): 1979-1984.

[19] Oluyemi, E.A., Feuyit, G., Oyekunle, J.A.I., Ogunfowokan, A.O., (2008): Seasonal variations in heavy metal concentrations in soil and some selected

crops at a landfill in Nigeria. International Journal of Environmental and Technology, 2(5): 89-96.
[20] Osakwe, S.A., Okolie, L.P., (2015): Physicochemical characteristics and heavy metals contents in soils and cassava plants from farmlands along a major highway in Delta State, Nigeria. Journal of Applied Science and Environmental Management, 19(4): 695-704.
[21] Reiling, E.A., Niekerk, W.A., Van, R.J., Rethman, N.F.G., (2011): An evaluation of *Panicum maximum.* South African Journal of Animal Science, 13: 85-91.
[22] Sandip, S.B., Vaneet, K., Navdeep, S., Vasudha, S., Jaswinder, S., Jatinder, K.K., Avinash, K.N., (2016): Physico-chemical properties and heavy metal contents of soils and Kharif crops of Punjab, India. Procedia Environmental Sciences, 35: 801-808.
[23] Singh, A., Sharma, R.K., Agrawal, M., Marshall, F.M., (2010): Health risk assessment of heavy metals via dietary intake of foodstuffs from the wastewater irrigated site of a dry tropical area of India. Food and Chemical Toxicology, 48(2): 611-619.
[24] Sulyman, Y. I., Abdulrazak, S., Oniwapele, Y. A., Ahmad, A. (2015): Concentration of heavy metals in some selected cereals sourced within Kaduna state, Nigeria. IOSR Journal of Environmental Science, Toxicology and Food Technology, 9(10): 17-19.
[25] US Government, (2001): Control of emissions of hazardous air pollutants from mobile sources: Final rule. Federal Registry, 66: 80-86.
[26] Uwah, E.I., John, K.O., (2014): Heavy metal levels in roadside soils of some major roads in Maiduguri, Nigeria. IOSR Journal of Applied Chemistry, 6(6): 74-78.
[27] Wang, W., Lai, Y., Ma, Y., Liu, Z., Wang, S., Hong, C., (2016): Heavy metal contamination of urban topsoil in a petrochemical industrial city in Xinjiang, China. Journal of Arid Land, 8(6): 871-880.
[28] Wang, M., Zhang, H., (2018): Accumulation of heavy metals in roadside soil in urban area and the related impacting factors. International Journal of Environmental Research and Public Health, pp. 1-11.
[29] Weckwerth, G., (2001): Verification of traffic emitted aerosol components in the ambient air of Cologne (Germany). Atmospheric Environment, 35: 5525–5536.
[30] Winther, M., Slentø, E., (2010): Reference: In heavy metal emissions for Danish road transport. National Environmental Research Institute, Aarhus University, Aarhus, Denmark, 99 p.
[31] Yan, X., Zhang, F., Zeng, C., Zhang, M., Devkota, L.P., Yao, T., (2012): Relationship between heavy metal concentrations in soils and grasses of roadside farmland in Nepal. International Journal of Environmental Research and Public Health, 9: 3209-3226.
[32] Yintao, L., Hong, Y., Dan, S., Yichen, J., Shichao, Z., Jun, Y., (2015): Heavy metal residues in soil and accumulation in maize at long-term wastewater irrigation area in Tongliao, China. Journal of Chemistry, 2015: 1-9.

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