Tanzania Journal of Engineering and Technology 2024, **43**(4):36-44
OPEN ACCESS articles distributed under Creative Commons Attribution Licence [CC BY-ND]
Websites: https://ajol.org/tjet; https://tjet.udsm.ac.tz

Copyright © 2024 College of Engineering and Technology, University of Dar es Salaam
ISSN 1821-536X (**print**); ISSN 2619-8789 (**electronic**)
https://doi.org/10.52339/tjet.v43i4.901

Regular Research Manuscript

Heavy Metals Pollution in Roadside Ecosystems

Lilian Matafu†, Godwill Mrema, and Rwaichi J.A. Minja

Department of Chemical and Process Engineering, College of Engineering and Technology, University of Dar es Salaam Tanzania.
†Corresponding author: lilianmatafu12345@gmail.com;
ORCID: https://orcid.org/0009-0000-7192-1497

ABSTRACT

Heavy metals refer to metallic elements that are characterized by having a relatively high density and they are toxic or poisonous even at low concentration. They are environmental pollutant owing to toxicity and longevity in atmosphere and ability to accumulate in living things via bioaccumulation. They tend to enter in different system such as food chain. Analyses of water, soil sediment and the surrounding growing plants (Cynodon dactylon and Cyperus species) for selected heavy metals (Cd, Pb, Zn and Cu) were conducted on a roadside pond located at Boko MSB, Dar es Salaam. Pond water, soil sediments and plant samples were collected from Boko MSB site and treated using appropriate methods of acid digestion (aqua regia digestion) involving sample preparation and digestion and analyses for heavy metals and physical-chemical parameters using atomic absorption spectrometry (GBC XPLOOR AAS). Physical-chemical parameters of pond water such as pH, electrical conductivity, total dissolved solids and turbidity were measured. The concentration of Cd and Pb in the water sample were 0.0637 mg/L and 0.995 mg/L, respectively, while the physical-chemical parameters of the pond water indicated a pH of 7.55, electrical conductivity of 184 µs. Based on the results of the study, the pond water is not safe for potable uses since it contains toxic heavy metals which are above WHO/TBS safe limit. The high concentration of the heavy metals was reflected in both the soil sediments and plants with Cd and Pb in soil samples being above safe limits while Cd, Pb, Zn and Cu in plant samples were also above safe limit.

ARTICLE INFO
Submitted: **Feb. 20, 2024**
Revised: **Nov. 18, 2024**
Accepted: **Dec. 15, 2024**
Published: **Jan. 2025**

Keywords: *Selected heavy metals, pond water, pond sediment, Cyperus species, Cynodon dactylon*

INTRODUCTION

There is major correlation between environment and biological system. This establishes different essential factors to the health of living things as well as water, soil and air. This interaction is major affected by environment pollutant such as heavy metals.

Environmental pollution is a process which involves introduction of undesirable and unwanted materials that change physical, chemical and biological characteristics of air, water and soil causing harmful effects to both animals and plants (Bharti, 2012). Heavy metals are among the chemical pollutants which are indestructible and most of them have toxic effects to the living things and surrounding environment (Macfarlane and Burchett, 2000).

The main sources of heavy metals are industrial wastes, municipal sewages, domestic wastes, natural resources extraction, synthetic fertilizers, and pesticides. One of major or more common source of pollution are anthropogenic sources of heavy metal pollution are traffic (vehicles) emissions, automobile workshops, wearing of tire and brake lining (Bharti, 2012). Heavy metals such as copper, cadmium, lead and zinc were found to be major sources of contaminants caused by traffic vehicle emissions along roadsides (Wang and Zhang, 2018). Once heavy metals get into the environment, they accumulate on the surface soil, sediments and in upper layers of bottom sediments in water basins.

After entering into the environment, heavy metals tend to mix with any existing substances and change their characteristics. High concentrations of heavy metals in surface layers of soil sediments have adverse effects on soil organisms and humans such as decreasing immunological defences, growth retardation and alteration of enzymatic activities of soil micro-organism (Singh *et. al*., 2011).

Some heavy metals are required by plants and animals for their metabolism at permissible levels (Ikhajigbe *et. al*., 2013). For example, heavy metals such as iron, copper, zinc, nickel and other trace elements are necessary for the functioning of the living biological system. Their excess or deficiency could however lead to a number of diseases such as neurologic disease. Heavy metals can enter the food chain through contaminated water, air and soil (Bharti, 2012).

Determination of levels of heavy metals in soil sediments and surface water (pond water) caused by different anthropogenic sources can reveal potential effects of their assimilation to living organism. Determination of physical-chemical parameters, such as, total dissolved solid, pH, electrical conductivity and temperature of pond water can reveal different levels of ionic distribution of heavy metal ions (Dixit et al., 2015). This study aimed at investigating deposition of selected heavy metals into a ponds' water along road side and correlation of heavy metals content in the water and sediment to the surrounding plants.

MATERIALS AND METHODS

Study Area

The sampling site for this study was at Boko MSB, which is one among small townships located at Bunju Ward, Kinondoni District in Dar es Salaam on the Coastal Eastern part of Tanzania (latitudes of 6o37'30.4212" S and longitude 4200144" E). The pond is along the roadside, close to the Ununio-Bagamoyo road junction, about 20 m away from the junction. It is surrounded by small growing plants (grasses) and very close to a motorcycle's parking area.

Sampling and Sampling size

Sampling was carried out from the different locations of the pond as shown on Figure 1. Pond water samples were collected from the pond (**Z**) while soil samples were collected into two groups. One group was collected in the pond (**S1**) followed by A second group of surface soil sediments was collected 10 meters away from the pond at two opposite directions, point A and B, and the samples are referred as **S2** and **S4**, respectively. Similarly at the same opposite locations at 10 cm deep, other soil sediment samples were collected and referred as **S3** and **S5**, respectively.Plant samples were collected into two groups. One group of two types of plant species (*Cynodon dactylon* (**S6**, and **S7**) and *Cyperus* (**S8**, and **S9**)) samples were collected 5 m away from the pond as (**S6**, **S8**) and (**S7, S9**) as shown in Figure 1.

Reagent and Equipment's

Analytical grade standards for Cu, Pb, Zn and Cd and all necessary reagents like HNO_3 and HCl acids were used. Equipment and apparatus used were hotplates, analytical balance, motor and pestle, beaker, funnels conical flasks, Whatman filter paper 40- and 2.00-mm sieve mesh.

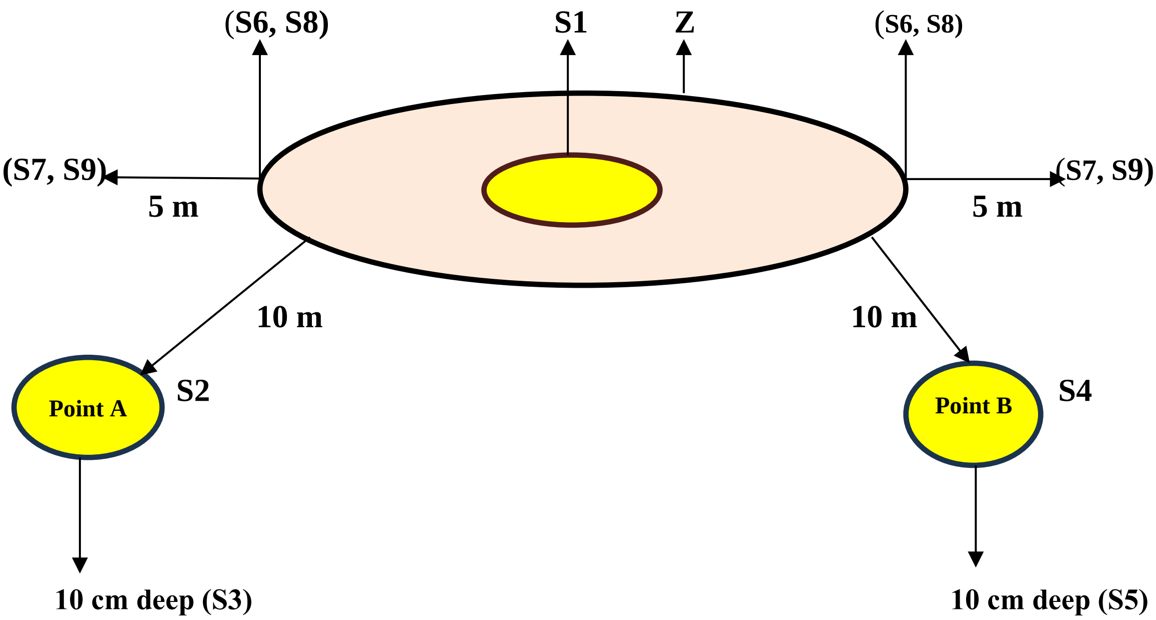

Figure 1: A sketch showing sampling points at Boko Chama roadside pond.

Sample Preparation and Digestion

Preparation and digestion of all samples were performed at Chemical and Process Engineering laboratory at the University of Dar es Salaam. Soil sample were air dried for three days to remove moisture and then they were ground using motor and pestle to uniform size while sieved soil sediment was digested in aqua regia (nitrosol chloride). The aqua regia was prepared by using conc. HCl and HNO_3 acids at a ratio of 3:1, respectively 3 g of sieved soil samples were weighed by using analytical balance and were added to clean and dry 200 ml conical flask.15 ml of aqua regia were added to the 200 ml conical flask contain sieved soil sediment sample and placed in hot plate for 2 hours the completion of digestion process the mixture was filtered through filter paper and placed into 100 ml volumetric flask and diluted with distilled water up to the mark.Pond water samples were treated with 5 ml conc. HNO_3 to dissolve suspended solids. Plant samples were thoroughly washed by distilled water, dried first in sunlight and then in oven at 50°C for approximately 12 hours. The dried plant samples were ground using motor and pestle to obtain small size and were passed through 2 mm mesh.0.5 g of plant powder was transferred to 25 ml conical flask. 5 ml conc. H_2SO_4 was added followed by 25 ml conc. HNO_3 and 5 ml conc. HCl. The mixture was digested on a hot plate for 2 hour and cooled to room temperature in 30 minutes. 20 ml of distilled water was added and the mixture was filtered using whatman filter 40 into 50 ml volumetric flask and filled with distilled water up to the mark ready for selected heavy metals analysis by AAS.

Determination of Physical-Chemical Parameters

pH of the soil sediment and pond water samples was determined by placed pH meter in soil. Electrical conductivity of soil sediment solution and pond water samples was determined by conductivity meter (CM100). Total dissolved solids for pond water were determined using total dissolved solid meter (HIMEDIA).

RESULTS AND DISCUSSION

The results of physical chemical properties of the pond water summarized in Table 1 show that, the pH of pond water was 7.55 while soil pH ranged from 8.38 to 8.68. According to the pH dependence solubility curve (Gustav and Lorch, 1995) at pH of 7.55 the solubility of Pb tend to be more as pH increases while solubility of Cd, Zn and Cu decreases. The electric conductivity of pond water and soil were 184 µS for water and that of soil ranged from 23 to 47 µS. The higher conductivity in water is due to presence of more dissolved ions in water than in soil. The turbidity of pond water samples was 8.07 NTU, which was lower than the upper TBS standards of drinking water of 25 NTU (TZS 789: 2008). The total dissolved solids (TDS) in the pond water samples was 92 ppm which was below the maximum allowable TBS standard for drinking water which is 500 ppm (TZS 789:2008). The low amount of TDS indicates low level of organic and inorganic dissolved solids in pond water. The concentration of Cd in the soil samples shown in Figure 2, indicate that, at all locations the Cd concentrations in soils were above the EPA standard of 1.0 mg/kg. The highest concentration of Cd was found in the soil sediment from the pond at S1 Figure 2, which was above 1.5 mg/kg.

Table 1: Physical-chemical parameters of pond water and soil sediment samples

Sample Location Coordinates	**Z (water)** **S**06°37.810' **E**039°09.175'	**S1 (soil)** **S**06°37.817' **E**039°09.177'	**S2 (soil)** **S**06°37.810' **E**039°09.169'	**S3 (soil)** **S**06°37.810' **E**039°09.169'	**S4 (soil)** **S**06°37.823' **E**039°09.180'	**S5 (soil)** **S**06°37.823' **E**039°09.180'
Parameter						
pH	7.55	8.55	8.38	8.60	8.68	8.56
Temperature (°C)	31.4	30.4	30.1	30.1	30.0	30.1
Conductivity (µS)	184	30	23	28	47	34
TDS (ppm)	92					
Turbidity (NTU)	8.07					
% Moisture content		0.67%	0.33%	0.38%	0.56%	1.04%

Key:
Z = Pond water sample S**1** = Pond sediment soil
S2 and **S4** = Surface soil at point A and B respectively 10 m away from pond
S3 and **S5** = Soil at point A and B respectively and 10 cm deep

The highest mean concentration of Zn was 39.25±3.783 mg/kg, Figure 3, was at point S5 at 10 cm deep (Figure 1 location B 10 m away from the pond). This is due to fact that heavy metals are mobile and they have potential to transfer to downward soil profile, either through the ground water or through soil plant roots uptake (De Matos *et al*., 2001). The concentration of Zn in soil samples might be coming from vehicles emissions, mechanical abrasion of engines, oil leakages and wearing and tearing of tyre linings (Opaluwa *et al.*, 2012: Pam *et al.*, 2013: Wang and Zhang *et al.*, 2018).

Figure 4 depicts concentrations of Cu in soil samples at different location. The highest mean concentration was 9.985±2.242 mg/kg at pond sediment soil. The Cu concentration was much below the EPA allowable concentration of 200 mg/kg. The small amount of Cu presence could be from natural sources.

Figure 5 shows mean concentration of Pb in soil samples at different locations. The highest mean concentration of 32.500±0.0231 mg/kg was at point S5 followed by point S3, both of which were at 10 cm deep (Figure 1 location A and B, 10 m away from the pond) as shown in Figure 1). This suggests a down movement of Pb from surface soil (leaching process). The high presence of Pb at the area could be due to vehicles emissions, resulting from the use of Pb gasolines in automobiles, use of lead batteries, and mechanical abrasion of engines (Opaluwa *et. al.*, 2012: Pam *et. al.*, 2013). All mean concentration values of Pb in soil samples were much above the EPA permissible standard limits of 1 mg/kg (EPA, 2002).

Figure 6 presents the mean concentration of Cd in two plant species (Cyperus (**S6** and **S7**) and *Cynodon dactylon* (**S8** and **S9**)) samples at two same locations (at the pond and 5 m from the pond). The highest mean concentration of Cd in *Cyperus species*, shown as S8, was 10.4±4.525 mg/kg at the pond (see S8 also in Figure 1) while highest mean concentration Cd in *Cynodon dactylon* was 11.4 ±0.5292 mg/kg, referred as S9 (see location of S9 in Figure 1). The presence of Cd in plant samples can be associated with vehicle emissions, mechanical abrasion of automobile engines and automobile fluid leakage (Opaluwa *et. al.*, 2012: Pam *et. al.*, 2013: Wang and Zhang *et al.*, 2018). The level of Cd, in the plant samples is quite substantial, which means the two types of plants species could be used to remediate removal of Cd in contaminated areas.

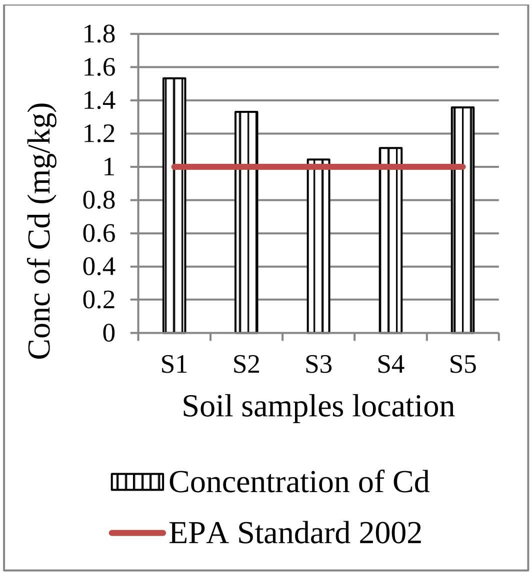

Figure 2: Mean concentration of Cd in soil samples compared to EPA permissible limit.

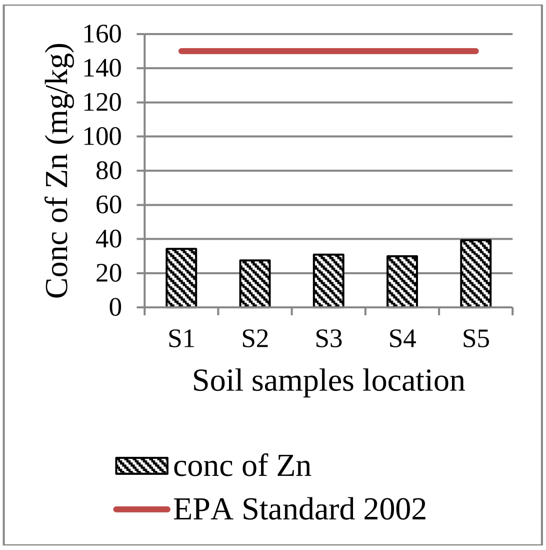

Figure 3: Mean concentration of Zn in the soil samples compared to EPA permissible limit.

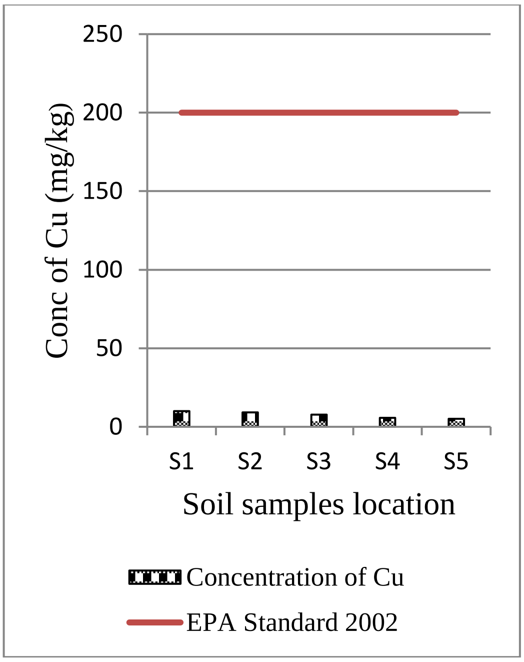

Figure 4: Mean concentration of Cu in soil samples compared to EPA permissible.

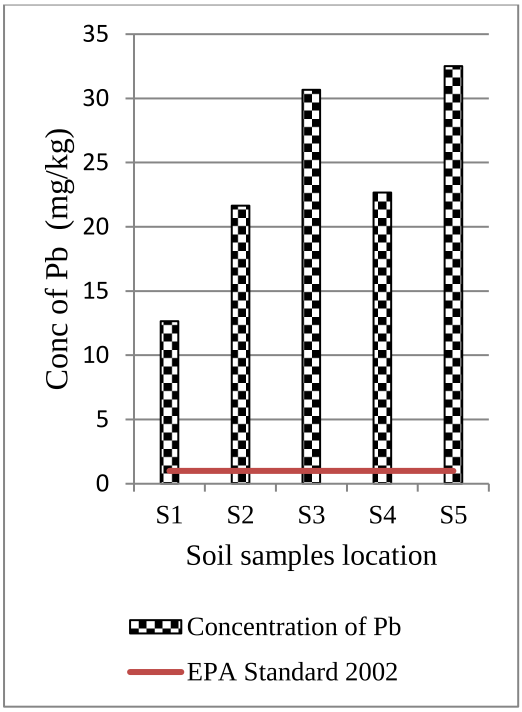

Figure 5: Mean concentration of Pb in soil samples compared to EPA permissible limit.

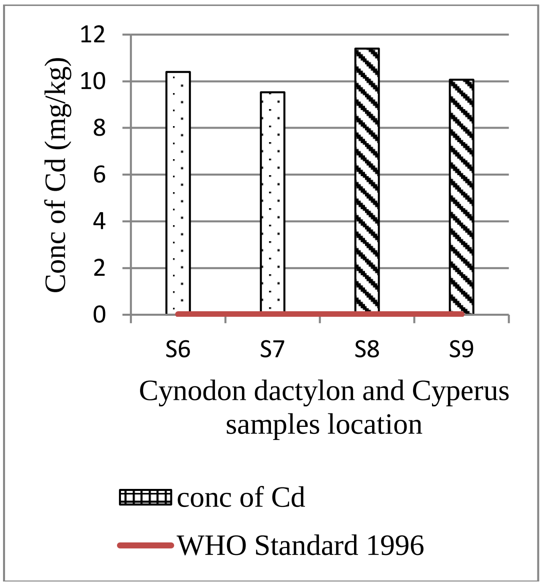

Figure 6: Mean concentration of Cd in plants samples compared to WHO 1996 permissible limits.

The mean amount of Cu in the two studied plants is shown in Figure 7 for the two plant samples at same locations. The highest mean concentration of Cu, 5 m away from the pond in *Cyperus species* was 13.47±2.572 mg/kg while the highest mean concentrations of Cu was 18.2±0.8485 mg/kg in *Cynodon dactylon* plant, shown as S7 and S9, respectively in Figure 7 and Figure1. The *Cynodon dactylon* uptake of Cu was more compared to *Cyperus species*. The concentration of Cu in plant samples might come from vehicle emission, mechanical abrasion of engines and corrosion of metals (Opaluwa *et al.*, 2012: Pam *et al.*, 2013: Wang and Zhang *et al.*, 2018).

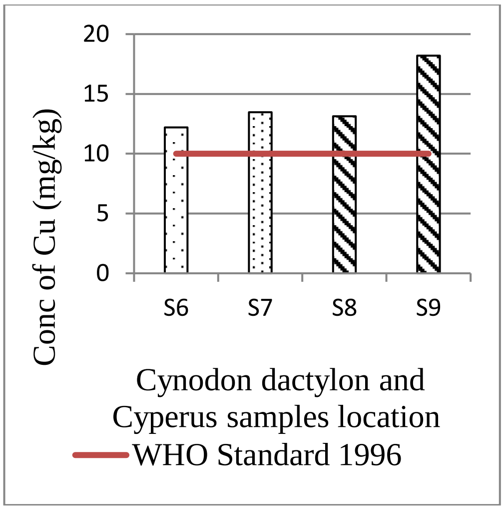

Figure 7: Mean concentration of Cu in plants samples compared to WHO 1996 permissible limit.

Figure 8 depicts mean concentration of Zn in different plant samples at same location. The highest mean concentration of Zn in *Cyperus species* was 59.65±0.4950 mg/kg 5 m away from pond (S7 in Figure1) while the highest mean concentration in *Cynodon dactylon* was 86.47±1.881 mg/kg at pond (S8 Figure 1). The mean concentration of Zn in plant samples might come from engine oil combustion, corrosion of batteries and metallic part such as radiator, wearing and tearing of tyre lining and vehicles emissions (Opaluwa *et al.*, 2012: Pam *et al.*, 2013: Wang and Zhang *et al.*, 2018).

Figure 9 shows mean concentration of Pb in the two plant samples, *Cynodon dactlon* and Cyperus, at same location. The highest mean concentration was 90.00±0.00 mg/kg in *Cyperus species* (S6) while the highest mean concentration in *Cynodon dactylon* was 83.00±7.071 mg/kg (S8). Concentration of Pb in plants samples is high and similar to the concentration of Pb is soil as shown in Figure 5 around the same area of the study. Similarly, the concentration of Pb in the water collected from the pond (Pont Z in Figure 1) as shown in Figure 10 is also high. This shows that at favourable physical chemical conditions as that shown in Table 1, solubility of Pb in water and its mobility in soil water, had led to its uptake by plants. The same reasons given for the presence of Pb in the soil applies for water and plants. The two naturally growing plants have a greater potential of being used for soil remediation of areas polluted with Pb.

Figure 10 indicates the mean concentration of selected heavy metals in pond water samples. The mean concentration of Cu in pond water sample was 0.07825 mg/L which was below 3 mg/L TBS standard limit. As shown in Figure 4, the mean concentration of Cu in the soil was quite low, therefore it's low concentration in the pond water correlates very well. Similarly, according to pH dependence solubility curve, Cu tend to be less soluble as pH increases compared to Cd and Pb (Gustav and Lorch, 1995).

The mean concentration of Zn in the pond water (Figure 10) was 0.2125 mg/L which is below 15 mg/L TBS standard. Compared to the amount of Zn in the surrounding soil, Figure 3, which also showed a concentration below the EPA allowable limit, there is an agreeable correlation of the amount in the surrounding pond soil and the pond water.

The mean concentration of Pb in the pond water (Figure 10) was 0.3798 mg/L. The relatively high concentration of Pb in water matches the high concentration of Pb in the soil (Figure 5) and the plants (Figure 9). The maximum allowable TBS concentration of Pb in water is 0.1 mg/L.

Compared to other heavy metals Pb and Cd are among the heavy metals which are very toxic. Thus, the results in Figures 5, 9 and 10, suggest that, the area around Boko MSB, is heavily contaminated with P. Figure 10 also show that, the mean concentration of Cd in the pond water was 0.0629 mg/L which was above TBS standard limit of 0.05 mg/L. The levels of Cd in the soil, Figure 6 and the pond water Figure 10, indicate that the levels of Cd in the area surrounding the Boko MSB Pond is contaminated with Cd beyond the acceptable limit.

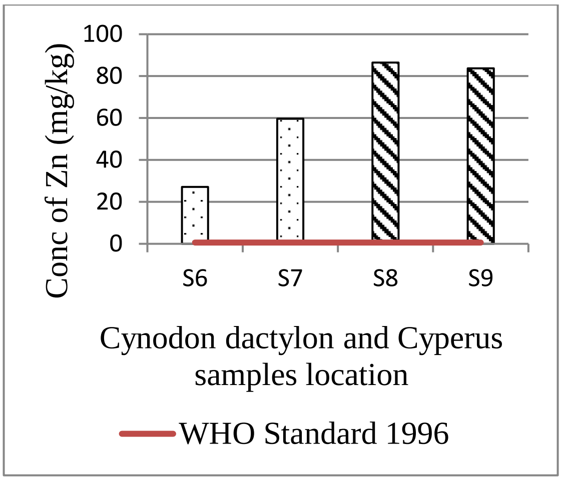

Figure 8: Mean concentration of Zn in plant samples compared to WHO 1996 permissible limit.

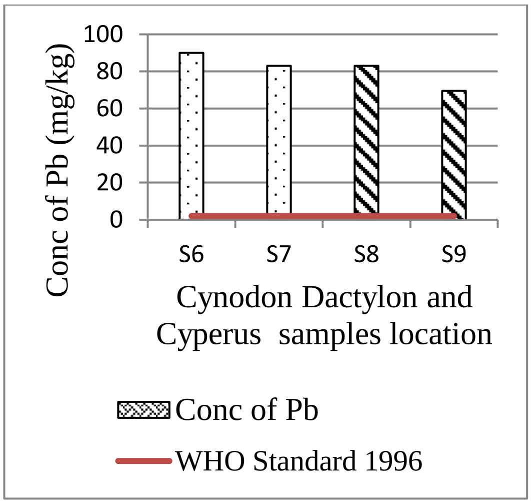

Figure 9: Mean concentration of Pb in plant samples compared to WHO 1996 permissible limit.

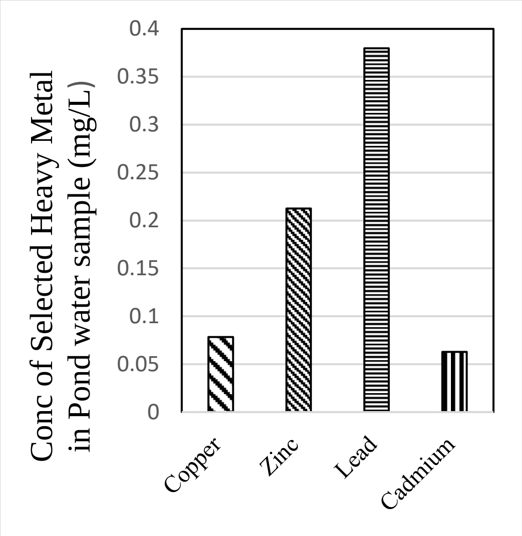

Figure 10: Mean concentration of Selected heavy metals (Cu, Zn, Cd and Pb) in pond water samples.

In general, there was high levels of selected heavy metal, both in the soil samples collected around the Boko MSB Pond and the water collected from the pond and analysed except for Zn and Cu. The Boko MSB Pond is located near by a road and there are activities of motorcycle parking which normally will involve some repair and washing. As such, heavy metals around the pond could be coming from emission of vehicles passing along the road, wearing and tearing of tyre, leakage of automobile oil, fuel burning, corrosion of batteries and metallic part such as radiators.

CONCLUSIONS AND RECOMENDATION

The study covered analyses of levels of selected heavy metals in roadside pond water, its sediments and surrounding plants at Boko MSB. The soil sediments, water and plant samples tested revealed that, the area is substantially polluted with the heavy metals Pb and Cd above the allowable limits. The other heavy metals tested which were Zn and Cu were not present in substantially high levels. The concentrations Pb and Cd in the soil and plant samples showed resemblance. The two naturally growing plants species (*Cynodon dactlon* and *Cyperus species*) have a greater potential of being used for soil remediation of areas polluted with the studied heavy metals Cd, Cu, Pb and Zn.

The pond water at Boko MSB should not be used for potable water since it contains some heavy metals above safe limits. The toxic heavy metals Cd and Pb were found to be above the safe limits. It is recommended to carry out further studies to investigate other variables such as microbiological parameter in order to identify types of micro-organisms that might be present in the pond water. Analysis of toxic hydrocarbon compounds such polyvinyl chlorides and aromatic compounds which could originated from traffic emissions, automobile oil leakage, wear and tear of engine and tyre linings.

REFERENCES

Bharti K. P, (2012). Heavy Metals in Environment. *Lambert Academic Publishing Germany Journal of Environmental Quality Vol.21, SN978-3-659-15133-0*.

De Matos, A.T, Fontes M.P.M, da Costa. and Martnez M. A, (2001). Mobility of Heavy Metals as Related to Soil Chemical and Mineralogical Characteristic of Brazzilian soil. *Env.Poll*, **111**, 429–435 doi:10.1016/s0269-7491(00)00088-9.

Dixit K. A, Pandey S. K, Mehta R. N. A, (2015). Study of the Physico-chemical Parameters of Different Pond Water of Bilaspur District, Chattishgarh, India. *Env. Skept and Critic*, **4**(3): 85–89.

Gulati K, Banerjee B, Lall SB, & Ray A. (2010). Effects of diesel exhaust, heavy metals and pesticides on various organ systems: possible mechanisms and strategies for prevention and treatment. *Indian J Exp Biol*., **48**(7), 710-21. PMID: 20929054.

Harmanescu, M., Alda, L. M., Bordean, D. M., Gogoasa, L., & Gergen, L., (2011). Heavy Metals Health Risk Assessment for Population via Consumption Vegetables Grown in Old Mining Area: A Case Study. Banet County, Romania. 64.

Ikhajigbe B, Anofelio G, Oshomoh. O, A. N, (2013). Change of Heavy Metals Contents of Wastes Engines Oil

Polluted Soil Exposed to Soil pH Adjustment. *British. Biotechnology. J*, **3**(2),158–168. doi: 10.9734/BBJ/2013/2374.

Khayatzadeh. J, and Abbasi E, (2010). The Effect of Heavy Metals on Aquatic Animals. *The First International Applied Geological Congress, Department of Geology, Islamic Azad University-Mashad Branch, Iran.*

acfalane. G.B and Burchett M.D, (2000). Cellular distribution of Cu, Pb, and Zn in Grey MagroveAviceminia marina (Forsk). *Vierh Aquatic Botanic*, **68**, 45–59. doi:10.1016/S0304-3770(00)00105-4.

Opaluwa O. D, Aremu M. O, Ogba L O, Abiola K. A, Odiba I. E, Abubakar M. M, N. N. O. (2012). Heavy Metal Concentrations in the Soils,Plant and Crops Grown Around Dump Sites in LafiaMetrolobis, Nassarawa state Nigeria. *Adv. Appl. Sci. Reas*, *ISSN:0976-*, 780–784.

Pam A. A, S. R. and O. J, (2013). Evaluation of Heavy Metals in Soil Around Auto Mechanic Workshop Cluster in Gboko and Makunndi Central Nigeria. *J. Environ. Chemi. Ecotoxicol.*, **5,** 298–306.

Rajan S, Firdus N.M. M, Appukutty M, and Ramasamy K, (2012). Effect of Climate Changes on Dissolved Heavy Metals Concentration Among the Recreation Park Tributaries in Pahang, Malaysia. *Biomed. Res*, *23*.

Salem H. M, Eweida E. A, and Azza. F, (2000). Heavy Metals in Drinking Water and their Impact on Human Health. *ICEM:Cairo University, Egypt*, 542–555.

Singh R, Gautam N and Gupta V, (2011). Heavy Metals and Living System. *Indian. J. of Pharmacology*, **43**(3), 246–253. doi:10.4103/0253-7613.81505.

Warmate A. G, Ideriah T. J. K, Tamunobereton A. R. I. U, (2011). Concentrations of Heavy Metals in Soil and Water Receiving Used Engine Oil in Port Harcout, Nigeria. *J. Ecol. Nat. Environ*, **3**(2), 54–57.

Xeudong, Y. Fan Z, Chen Z, Man Z, Lochan. P. D, and Tandog. Y, (2012). Relationship between Heavy Metal Concentration in Soil and Grasses of Roadsides farmland in Nepal. *Int.J. Env. Res Public Heal.*, 3209–3226.

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*, **15**(6), 1064. doi:10.3390/ijerph15061064.