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Occurrence and Distribution of Heavy Metals in Roadside Soils and Plants along Major Urban Roads of Zanzibar

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Abstract: The environmental pollution by heavy metals from automobile sources raises attention. This study reports the occurrence and distribution of heavy metals in roadside plants and soils along urban major roads in Zanzibar. Fifteen samples, nine of the plants and six of the soils from selected major roads were analyzed for Mn, Pb, Zn, Cu, Ni and Cd contents using Energy Dispersive X-Ray Fluoresence (EDXRF). Ranges of metals content in soil and plants were 6.07-191.69 mg kg^{-1} and 101.2 mg/kg-138.97 mg/kg for Pb; ND –36.22 mg kg^{-1} and 15.56-63.11 mg/kg for Cu; 218.70-393.98 mg/kg and 26.22-294.62 mg/kg for Mn; 88.74-474.22 mg/kg and 34.29-180.99 mg/kg for Zn; 0.88-23.98 and 13.58-74.80 mg/kg for Ni respectively. Cd was not detected in both soils and plants. Metals content investigated in the soil except for Pb and Zn, are within the safety limit recommended by WHO whilst in plants were above the maximum tolerance level as recommended in different studies. Contamination assessment status of the metals was made using mathematical models in terms of contamination factor, pollution load index, and geoaccumulation index. All the models approved that the soils were considerable to strongly contaminated by Zn and Pb respectively.

Key words: heavy metals, roadside soil, plants, contamination factor, pollution load index, geoaccumulation index, maximum tolerance level

1. Introduction

The pollution of soil by heavy metals from automobile sources is a matter of environmental concern [1]. These metals are released during different operations of the road transport since are present in fuel as anti-knock agents and this leads to contamination of air and soils on which plants are grown [2]. Lead, cadmium, copper, iron, nickel, and zinc are the major metal pollutants of the roadside environments and are released from fuel burning, wear out of tires, brake wear, leakage of oils, corrosion of batteries, metallic parts such as radiators, road abrasion [3]. Automotive emissions are the most effected contaminants sources for heavy metals pollutants in the roadside environment [4]. Heavy metals pollution is a universal problem because these metals are indestructible and most of them have toxic effects on living organisms, when permissible concentration levels are exceeded [5]. Plants grown in rich contaminated soil with heavy metals results in transfer of substantial amount of potentially toxic metals into the food chain as a result of their uptake by edible plants [6]. Cities have become islands of toxic chemicals from the unrestrained use of fossil fuel in vehicles. Urban people are most affected and the worst sufferers are traffic policemen who are particularly close to the fumes of automobile exhaust. Studies have indicated that there is high rate of occurrence of respiratory tract infections, digestion, and skin irritation among the traffic police and significant

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numbers of them become victim of lungs disorder [7]. The high heavy metal content in urban roadside and urban side soil and plant samples is mostly due to the density of traffic, which is considered one of the major sources of heavy metal contamination, especially of Pb, because unleaded petrol is expensive and people use leaded petrol instead [8]. When heavy metals are present in high concentrations in the environment, they result in health hazards by adversely affecting the nervous, blood forming, cardiovascular, renal and reproductive systems. They also result to reduction in intelligence, attention deficit and behavioral abnormality, as well as contribute to cardiovascular disease in adults [9]. The dispersion of heavy metals in roadside soils is influenced by meteorological conditions like wind, rainfall, profiles or traffic intensity and the concentrations of metals in the roadside soil are influenced by the same factors [10] and by soil parameters. The distribution of heavy metal is strongly but inversely correlated with the increase in the distance from the road, i.e., the concentrations of heavy metals decrease with increasing roadside distance [11]. Contamination of heavy metals in roadside soil and grasses was reported from different countries worldwide such as Massadeh A. M., Tahat, M. Q., Jaradat M., Al-Momani I. F. (2004) [12] reported lead and cadmium of roadside soils in Irbid city, Jordan. Akbar K. F., Hale W. H. G., Headley A. D., and Athar M. (2006) [11] in Northern England reported on, cadmium, copper, lead and zinc, Xuedong Yan, Zhang F., Zeng C., Zhang M., Devkota L. P., and Yao T. (2012) [3] reported on (Cu, Zn, Cd, and Pb) concentrations in roadside farmland soils and corresponding grasses around Kathmandu, Nepal, Inoti K. J., Kawaka F., Orinda G., and Okemo P. (2012) [13] in Thika town Kenya revealed that the concentrations of lead, zinc and cadmium in vegetables. Addo M. A., Darko E. O., Ordon C., Nyarko B. J. B., and Gbadago J. K. (2012) [5] reported on (Pb, Cu, Zn, Mn, and Ni) in Ketu South District, Fergusson J. E., Forbes E. A., Schroeder R. J., and Ryan D. E. (1986) [14] in New Zealand reported on higher content of lead in roadside soil. According to figures released from Ref. [15] in Zanzibar the number of vehicles rose significantly from 17,845 in 2006 to 23,592 in 2014 and fuel consumption in vehicle rose significantly from 29,222,100 L in 2003 to 75,796,903 L in 2015. Zanzibar has been experiencing an unprecedented increase in vehicular traffic which is suspected to be having contamination effects on soils along heavily used roads in the country. However there is limited or no existing data on heavy metals contamination in roadside soils and grasses. Hence, this study was aiming to ascertain the occurrence and distribution of heavy metals in roadside soils and grasses of major roads of Unguja Island.

2. Materials and Methods

2.1 Study Area

The study was conducted in major roads of Unguja Island, Zanzibar Tanzania. Zanzibar comprises two sister islands of Unguja (also referred as Zanzibar island) and Pemba located between latitude 4° and 6°S of the Equator and between 39° and 40°E of the Greenwich Meridian. Zanzibar is a part of the United Republic of Tanzania, off the coast of Mainland Tanzania, East Africa.

Unguja (also referred to as Zanzibar Island or simply Zanzibar) is the largest and most populated island of the Zanzibar archipelago, in Tanzania. It lies between latitude 6.16°S and longitude 39.2°E. Unguja is an island, about 85 kilometres (53 mi) long (north-south) and 30 kilometres (19 mi) wide (east-west) at its widest, with an overall area of about 1,666 square kilometres (643 sq mi) [16].

2.2 Sample Collection and Analysis

One soil and one plant samples each were collected from each site along the distance of the road. Soil samples were collected from the upper soil layer of 0-5 cm. by hand auger and kept in plastic bag then stored. At the sampling sites, a Geographical Positioning

System was employed to record the geographical position. The soil samples were spread in a thin layer on a clean piece of mate and left until air dried. All clods, crumbs and plant materials were removed from the soil sample and discarded. Then the soil samples were ground in a mortar and pestle and subsequently sieved by using, a set of stainless steel sieve mesh of different sizes including 150 µm, into fine particles like powder. A sieve mesh set, mortar and pestle were all washed with acetone after each sample treatment to remove cross contamination between samples. Subsequently each sample was kept in a separate clean polythene bag with appropriate marking for chemical analysis. The plant samples, were washed with distilled water and set dried in an oven of about 60°C temperature over night, later samples were grounded by using electric grinder and subsequently sieved using the same sieve mesh set as in soil samples (different sizes including 150 µm) into fine particles like powder. The fine powder plant samples will be kept in a separate clean polythene bag with appropriate marking and transported to Arusha TAEC laboratory for chemical analysis. Before the XRF analysis, 6.0 g of the dry standard powdered samples was mixed well with binder including starch powder about 1.35 g, then homogenized and pressed into the presser machine to a pressure of 15 bar to produce pellets. The pellets were then placed in the well labelled holders and were then inserted into the XRF machine (45 kV and 10 mA) for elemental content analysis.

Table 1 Characteristics of sampling area.

Major Road	Station Name	Station ID	North	South	No of vehicles per hour/Site Description
Nyerere Road	Air Port	S01	6°12'58''	39°13'12''	SU, 900v/h, Straight Road (SR) Near to Airport
Nyerere Road	K/Samaki	S02	6°12'39''	39°13'2''	SU, 900v/h, near petrol station, SR.
Nyerere Road	K/Samaki School	S03	6°12' 7''	39°12'44''	SU, 900v/h, Road Intersection (RI)
Nyerere Road	Mazizini	S04	6°11'42''	39°12'35''	U, 900v/h, Road Bend (RB)
Nyerere Road	Zanzibar Social	S05	6°10'47''	39°12'16''	U, 900v/h, Slope on left edge of the road, SR
Nyerere Road	Mnazimmoja	S06	6°10'15''	39°11'35''	U, 900v/h, Near RB.
BenjaminMkapa	Haile Selasie	S07	6°9'56''	39°11'32''	U, 1560v/h, traffic signs, bussy near RI.
BenjaminMkapa	Malindi Policce	S08	6°9'32''	39°11'40''	U, 1560v/h, traffic signs, market, near RI.
Mizingani Road	Bandarini	S09	6°9'31''	39°11'32''	U, 1620v/h, bussy, near to Sea Port, Road with Speed Control.

SU- Sub Urban, U - Urban.

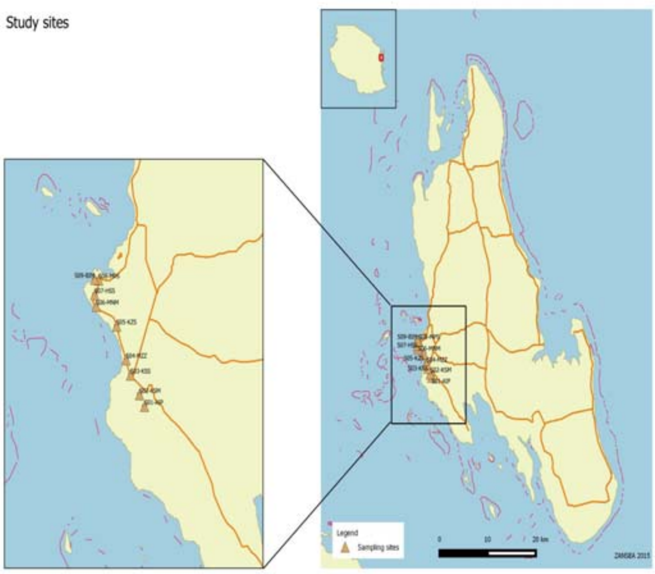

Fig. 1 Sampling Map of Zanzibar (Unguja Islands) showing location of sampling stations in major roads.

The Soil montana Standard Reference Material (SRM) was used for validation to ensure the accuracy of the results [17].

Recovery tests were conducted for the purpose of monitoring the efficiency of the analytical procedure, the recovery % range between 87-92% hence, the laboratory analysis was deemed to be accurate and valid.

2.3 Assessment of Metals Contamination

2.3.1 Contamination Factor (CF)

The level of contamination of soil by metal is expressed in terms of a contamination factor (CF) calculated as:

$$CFi = Cm/Cb \quad (1)$$

where CF is the contamination factor, Cm Sample is the concentration of the metal in the samples analyzed and Cm Background is the metal concentration in the control sample. Where the contamination factor $CF < 1$ refers to low contamination; $1 \leq CF < 3$ means moderate contamination; $3 \leq CF \leq 6$ indicates considerable contamination and $CF > 6$ indicates very high contamination [18].

2.3.2 Pollution Load Index (PLI)

Each site was evaluated for the extent of metal pollution by employing the method based on the pollution load index (PLI) developed by [19], as follows:

$$PLI = (CF_1 \, X \, CF_2 \, X \, CF_3 \, X \, CF_4 \, X \, CF_5 \, X \, CF_n)^{1/6} \quad (1)$$

where n is the number of metals studied (6 in this study) and CF is the contamination factor calculated as described in Equation 1. The PLI provides simple but comparative means for assessing a site quality, where a value of $PLI < 1$ denote perfection; $PLI = 1$ present that only baseline levels of pollutants are present and $PLI > 1$ would indicate deterioration of site quality [19].

2.3.3 Geoaccumulation Index

The geoaccumulation index (Igeo) values were calculated for heavy metals as introduced by [20], the mathematical representation is as follows:

$$Igeo = \log2\ (Cn/1.5 \times Bn) \quad (3)$$

Table 2 The Igeo classes with respect to soil quality.

Igeo value	*Igeo* class quality	Designation of soil
5	6	Extremely contaminated
4-5	5	Strongly to extremely contaminated
3-4	4	Strongly contaminated
2-3	3	Moderately to strongly contaminated
1-2	2	Moderately contaminated
0-1	1	Uncontaminated to moderately contaminated
0	0	Uncontaminated

where Cn is measured concentration of metal in the soil, and Bn is the geochemical background for the same element which is taken from the literature (average shale value as described by Turekian K. K. and Wedepohl K. H. [21]. The factor 1.5 is introduced to include possible variations of the background values that are due to lithologic variations. According to Muller G. [20], there are seven grades or classes of the geoaccumulation index.

3. Results and Discussion

3.1 Results of Heavy Metals in Roadside Soils and Plants

Table 3 Total heavy metals content (mg/kg) in soil samples.

Sample ID	Mn	Ni	Cu	Cd	Zn	Pb
S04	487.68	12.36	16.12	ND	195.05	33.57
S05	247.13	0.88	ND	ND	88.75	06.07
S06	342.08	08.63	15.00	ND	220.37	31.97
S07	218.70	01.43	06.89	ND	142.32	27.69
S08	484.88	07.58	17.50	ND	193.12	65.47
S09	584.13	23.98	36.22	ND	474.22	191.69
Min	218.70	0.88	ND	ND	88.75	06.07
Max	584.13	23.98	36.22	ND	474.22	191.69
Mean	393.98	09.14	15.28	ND	218.97	59.41
Aver Sha	950	68	45	0.3	95	20

ND: Non - Detected

Ave Shale: Average Shale

Table 4 Total heavy metals content (mg/kg) in plants samples.

Sample ID	Mn	Ni	Cu	Cd	Zn	Pb
S01	111.59	65.44	24.16	ND	159.76	101.73
S02	294.62	74.80	32.80	ND	180.99	138.97
S03	59.52	66.34	22.58	ND	106.77	101.48
S04	53.02	66.73	18.63	ND	151.43	102.7
S05	94.69	63.51	16.98	ND	2.09	101.3
S06	32.06	62.53	15.56	ND	34.29	101.2
S07	26.22	63.23	17.66	ND	41.69	103.4
S08	53.06	62.96	17.99	ND	38.89	103.8
S09	34.36	13.58	63.11	ND	92.70	103.38
Min	26.22	13.58	15.56	ND	38.89	101.2
Max	294.62	74.80	63.11	ND	180.99	138.97
Mean	84.348	59.90	25.49	ND	99.85	106.39

N.D – Not Detected.

3.2 Distribution of Heavy Metal in Roadside Soils Samples

The levels of Mn, Ni, Cu, Cd, Zn and Pb of the roadside soils are presented in Table 3 above. The levels of manganese (Mn), Zinc (Zn), lead (Pb), Copper (Cu), Nickel (Ni) and Cadmium (Cd) were ranged as 218.70-584.13 mg/kg, 88.75-474.22 mg/kg, 6.07-191.69 mg/kg, ND-36.22 mg/kg, 0.88-23.98 mg/kg respectively. And their mean were 393.98 mg/kg, 218.97 mg/kg, 59.41 mg/kg, 15.28 mg/kg, 9.14 mg/kg respectively. Cadmium was not detected at all in soil and hence plants samples. Therefore the content of the metals in increasing order is given as Mn > Zn > Pb > Cu > Ni > Cd.

The relatively high contents of all metals, i.e., Lead, Zinc, Copper, Manganese, and Nickel were found at S09, site was near to Sea Port with high traffic volume (1620 v/h), urban area, extremely busy with socio-economic activities, road with speed control (RSC) which characterized by a lot of braking and "start stop", vehicles are often moving slowly as a result of the heavy traffic jam in this area, and these may account for the high content of those metals.

Spatially the content of all heavy metals concerned, revealed the insignificant variation ($p > 0.05$) which may be endorsed to the wide spread of heavy metals contamination along sides of the selected major roads of Zanzibar Island.

The sources of all metals are exhaust emission from motor vehicles, example Lead particulates are from leaded petrol vehicles [22], wearing down of automobile tyres [23], lubricating oil, yellow road paints and grease. Additionally Copper are from engine wear, brake linings [24], metal plating, moving engine parts. According to [25], manganese are associated with traffic related sources such as corrosion of metallic part, concrete materials, from roads and tear and wear of tires and engine parts. High content of nickel is from motor-vehicles that use nickel gasoline [26]. Finally the fragmentation of tyres, motor oil and grease has been concerned for higher content of Zn [27, 28].

In comparison, Lead contents established in the major roadside regions of Zanzibar Island are much lower compared to those cities reported in Table 4 except in Ketu South District and Ottawa in which itself was higher. Zinc content are much higher than Ketu, Ottawa, Dhaka, Islamabad, Calcuta but lower than New Zealand, Amman, Oslo, Honkong, Shanghai, and Luanda. For Nickel, Copper, and Manganese their contents in the roadside soil of this study were lower

Table 5 Heavy metal (mg/kg) from different countries in the world as compared to the current study.

City	Cu	Mn	Ni	Pb	Zn	Reference
Calcutta	44.0	-	42.0	536.0	159.0	[29]
Islamabad	52.0	-	23.0	104.0	116.0	[30]
N. Zealand	90.8	-	-	1223.0	716.0	[25]
Amman	177.0	-	88.0	236.0	358.0	[31]
Dhaka	304.0	-	54.0	205.0	169.0	[32]
Oslo	123	830	41.0	180	412.0	[33]
Ottawa	65.8	431.5	15.2	39.1	112.5	[34]
Hong Kong	110.0	594.0	28.6	120.0	3840.0	[35]
Shanghai	196.8	-	83.9	294.9	733.8	[36]
Luanda	42.0	-	10.0	315.0	317.0	[37]
Ketu-south District Zanzibar Tanzania	60.53 15.28	564.42 393.98	73.45 9.14	22.89 59.41	133.52 218.97	[05] This study

than reported in those cities in Table 4, but for Nickel were similar to that of Luanda and to some extent of Ottawa.

Table 6 Mean values obtained in this study in comparisons with maximum allowed levels for different countries and WHO in mg/kg.

Metal	Austria	Canada	Poland	Japan	UK	Germany	U.S.A	WHO	Present study
Cd	5.00	8.00	3.00	-	3.00	-	0.70	3	ND
Cu	100	100	100	125	100	50	100	100	15.28
Ni	100	100	100	100	50	100	500	50	09.14
Pb	100	200	100	400	100	500	200	100	59.41
Zn	300	400	300	250	300	300	300	300	218.97
Mn	-	-	-	-	-	-	-	1000	393.98

ND - Non Detected

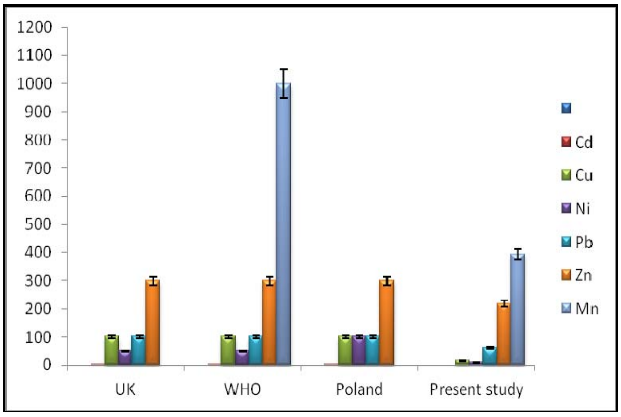

Fig. 2 Comparison of heavy metals with international standards.

Results show that the average content of all heavy metals is lower than the maximum allowed levels of different countries and WHO suggesting that the study area were not contaminated with heavy metals. However the content of Lead at S09 was above the maximum allowed levels set by WHO, UK, Poland and Austria so the site was highly polluted hence the possibility of posing some health problems associated with the excess Lead levels in soils for instance, dust from these contaminated sites could affect those people that live closer to the sites [38].

3.3 Distribution of Heavy Metal in Roadside Plants

The results of the levels of metals of the roadside plants of species *Paspalidium flavidum* (Yellow Watercrown Grass) S01, S02, S04 and S05. Cynodon nlemfuensis S03) and leaves (Tipuana tipu S06 and S08. Saraca indica S07. Ligustrum japonicum S09) from the different sampled sites along selected major roads are presented in Table 4. The metals were ranged as follows Pb (101.2-138.97) mg/kg with the mean of 106.39 mg/kg, Zn (38.89-180.99) mg/kg and mean of 99.85 mg/kg, Mn (26-294.62) mg/kg, and mean of 84.35 mg/kg, Ni (13.58-74.80) mg/kg its mean was 59.90 mg/kg, Cu (15.56 to 63.11) mg/kg with its mean of 25.49 mg/kg and ND. Therefore the concentration of the metals in increasing order is given as Pb > Zn > Mn > Ni > Cu > Cd.

The relatively high contents of all metals in different species of grasses (Lead, Zinc, Copper, Manganese, and Nickel) were found at S02 in *Paspalidium flavidum*, except Copper that was found it S09 in *Ligustrum japonicum*. The S02 where the *Paspalidium flavidum* were grown was near to Petrol station and had traffic volume of 900v/h. Consequently high exhaust emission, brake linings, tyre wear, metallic engine parts, motor oil and grease etc from the vehicles might penetrate the corresponding soil which Paspalidium flavidum were grown and hence high metals content into the grasses. Moreover metals exhaust emissions into the atmosphere may be deposited on leaf surfaces and absorbed inside plant cells [39].

S09 where maximum concentration of Copper was found in *Ligustrum japonicum* was urban busy area, with high traffic volume (1620 v/h) and congestion giving rise to high exhaust emission enriching the metals content to the soil and hence high level of Copper to the plants.

Spatial, the heavy metals concentrations in plants samples did not vary significantly ($p > 0.05$) which may be attributed to the wide spread of heavy metal contamination in plants along the selected areas of major roads in Zanzibar Island.

However the metals average concentration of different species of plants in the present study were seen to exceed the recommended toxicity level for plants such as Lead its average concentration was 106.39 exceeds 2-6 mg/kg toxicity level for plants [40] so the plant were highly polluted, According to [41] a critical toxic level of Zn for plants is 100 mg/kg [42], which is similarly as the mean value obtained from the present study 99.85 mg/kg, hence generally the plant were at risk pollution. The mean of Copper in plants was 25.49 mg/kg exceeds the critical toxic level of copper in grasses 20-30 mg/kg [43] for most plants and thus the plants were polluted. A critical toxic level of Manganese for plants is 400-2000 mg/kg. The mean value 84.34 mg/kg was lower than the critical toxic level of Manganese, so the plants were not polluted with respect to this metal.

Different researchers had reported on heavy metals in concern such as Lead content in grasses of this study are much higher compared to those reported by Ref. [44] 0.17±0.02 mg/kg Polygonatum *verticillatum*, Nigeria 0.04±0.01-0.30±0.01 mg/kg [45] and Malaysia 11.0-20.9 mg/kg Centella *asiatica* [46], 1.80 to 5.70 mg/kg [47].

Zinc content of plants in this study was higher than reported in *Polygonatum verticillatum* 38.8±0.05-60.0±0.17 [44], 0.02±0.10-0.06±0.10 mg/kg in Nigeria [45].

The average concentration of Nickel in plants was higher than reported in Islamabad Pakistan 23 mg/kg [30], Konya Turkey 15.59 mg/kg [8].

3.4 Correlation Coefficient Matrix for Heavy Metals Content of Roadside Soils and Plants.

Using **Pearson Correlation (r)** from Table 7, the result indicates that some elemental pairs in soils have very strong positive significant correlations with each other. Some metals show strong significant positive correlation such as Mn with Ni (r = 0.891*, $p < 0.05$), and Cu (r = 0.863*, $p < 0.05$). Ni with Cu (r = 0.924*, $p < 0.05$), Zn (r = 0.954*, $p < 0.05$) and Pb (r = 0.895*, $p < 0.05$). Cu with Zn (r = 0.927*, $p < 0.05$) and Pb (r = 0.878*, $p < 0.05$). Finally Zn with Pb (r = 0.965*, $p < 0.05$). For the case of plants Mn showed highly significant positive correlation with Ni (r = 0. 912*, $p < 0.05$) and Cu (r = 0.900*, $p < 0.05$). Similarly Ni content in plants showed highly significant positive relationship with Cu (r = 0.918*, $p < 0.05$), and Pb (r = 0.902*, $p < 0.05$). Strong positive correlations signify that each paired elements have common anthropogenic contamination sources [48]. Other inters relationships among the constituents element of soil and plants were insignificant correlated.

Table 7 Pearson correlation of heavy metals in soil and plants.

	Cr	Mn	Fe	Ni	Cu	Cd	Zn	Pb
Cr	1	-0.207	-0.160	-0.253	-0.259	-0.127	-0.424	-0.135
Mn	0.798	1	0.957*	0.912*	0.900*	-0.109	0.699	0.923*
Fe	0.716	0.849*	1	0.942*	0.886*	-0.051	0.614	0.986*
Ni	0.799	0.891*	0.981*	1	0.918*	0.096	0.783	0.902*
Cu	0.658	0.863*	0.926*	0.924*	1	0.168	0.723	0.809
Cd	0.314	0.384	-0.061	-0.008	-0.098	1	0.049	-0.151
Zn	0.604	0.777	0.983*	0.954*	0.927*	-0.213	1	0.531
Pb	0.522	0.767	0.961*	0.895*	0.878*	-0.093	0.965*	1

* Correlation Significant ($P < 0.05$). The bolded value for plants

3.5 Transfer Factors from Soils to Plant

Transfer factor (TF) defined as the ratio of trace metal concentration in plant and trace metal concentration in soil were computed in order to surmise the extent of transfer of soil trace metals into the plant. The transfer factor for Pb, Mn Zn, Cu and Ni from the soil to the different species of the plants are displayed in Table 8.

Table 8 Transfer factors (TF).

	Mn	Ni	Cu	Zn	Pb
S04	0.11	5.39	1.16	0.78	3.06
S05	0.38	72.17	-	1.04	16.69
S06	0.09	7.25	1.04	0.16	3.17
S07	0.02	1.69	2.56	0.29	3.73
S08	0.11	8.31	1.03	0.20	1.56
S09	0.06	0.57	1.74	0.19	0.54
Mean	0.77	95.38	7.53	2.66	28.75

The transfer factor of Pb range from 0.54 to 16.69 and the mean of 28.75, this revealed that the lead uptake in this study was high, however at Bandarini (S09) Pb is relatively transferred to the plant poorly (TF = 0.54) hence less lead was absorbed by plant, beside of the higher soil lead content at this site resulting into minimizing the risk level of the plant due to Lead. The relatively mean TF of Mn and Zn exposed that their uptake to the plant were scantily. Mean TF of Ni implies that its uptake to the plant was incredibly high.

3.6 Assessment of Pollution Level

Table 9 Contamination factors of heavy metals.

	Contamination Factors				
	Mn	Ni	Cu	Zn	Pb
S04	0.51	0.18	0.36	2.05	1.68
S05	0.26	0.01	-	0.93	0.30
S06	0.36	0.13	0.33	2.32	1.59
S07	0.23	0.02	0.15	1.49	1.38
S08	0.51	0.11	0.39	2,03	3.27
S09	0.61	0.35	0.80	4.99	9.58

3.6.1 Contamination Factor (CF)

Using the contamination factor categories previously described in methodology, all samples site suffered low contamination by all metals except Pb and Zn. These metals suffer moderate contamination in S04, S06, and S07 while S08 experienced moderate contamination by only Zn. However S08 and S09 had considerable contamination by Pb and Zn respectively. It was also observed that Sample site S09 showed very high contamination by Pb. The trend in the contamination factor as determined was S05 < S07 < S04 < S06 < S084 < S09.

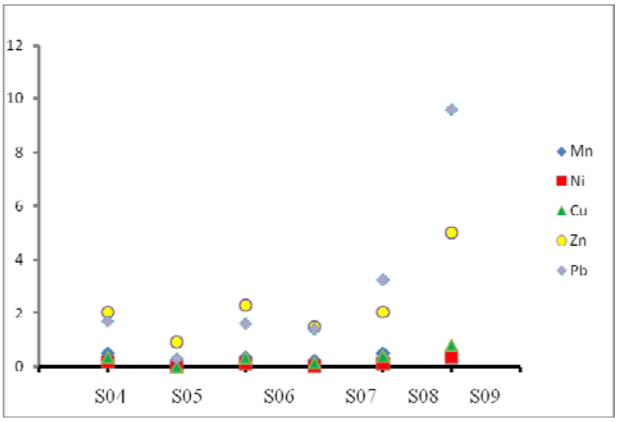

Fig. 3 Contamination factor of heavy metals along the roadside soil.

3.6.2 Pollution Load Index

Based on the results the overall degree of contamination (PLI) by the five (5) metals is of the order S09 > S08 > S04 > S06 > S07 > S05. Results show that the PLI both sites perfect (not polluted) except for **S09** with **PLI > 1 (1.52)** indicating **deterioration** of the site quality.

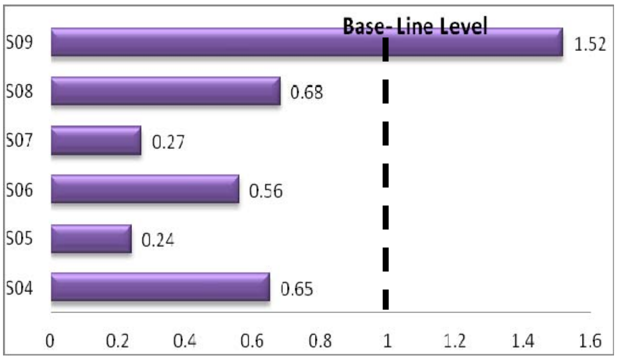

Fig. 4 Pollution load index of heavy metals along the roadside soil.

3.6.3 Geoaccumulation Index of Heavy Metals

Table 10 Geoaccumulation index of heavy metals.

		Geoaccumulation Index			
Location	Mn	Ni	Cu	Zn	Pb
S04	-1.56	-11.86	-2.07	0.45	0.162
S05	-2.53	-6.85	-	-0.68	-2.31
S06	-2.06	-3.49	-2.17	0.63	0.09
S07	-2.52	-6.16	-3.29	0.00	-0.12
S08	-1.56	-3.76	-1.95	0.44	1.12
S09	-1.28	-2.09	-897	1.74	2.68

According to calculated geoaccumulation index (Igeo) values it revealed that Geoaccumulation index ranged from unpolluted to moderately to strongly polluted soil quality. Spatially showed that S05 and S07 were unpolluted with negative Igeo values for all metals (below zero). S04, S06, S08 and S09 were unpolluted due to Manganese, Nickel, and Copper with Igeo values also below zero. However S04, S06 were unpolluted to moderately polluted for Zn and Pb and S08 for only Zn. S08 and S09 were moderately polluted by Pb and Zn respectively. With respect to Pb S09 were moderately polluted to strongly polluted. This clearly reveals that high levels of Zn, Pb, were due to anthropogenic activities, especially soils with moderate to high levels of geoaccumulation indexes were situated near of heavy traffic vehicular emissions.

4. Conclusion

Heavy metals were positively identified, for the first time, in the roadside soils and plants of Unguja Island, and their content in the soil were not at risk level. However, the Lead content in S09 was above maximum permissible level recommended by WHO. In case of plants all heavy metals were above maximum permissible level except for Manganese. Heavy metals distribution seems to be wide spread in major roadside of Unguja Island since $p > 0.05$. Even though, for now they did not cause serious effect on the surrounding organisms, the prospect of possible chronic effect caused by Lead and other toxic heavy metals could be observed. It is urgent for Zanzibar Government to accomplish the ecological risk appraisal studies concerning the level of contamination of Lead and its distribution in all major roads of Zanzibar and blueprint national and international policies for roadside environment conservation, supervision and carefully planning the sustainable use and execution of natural resources.

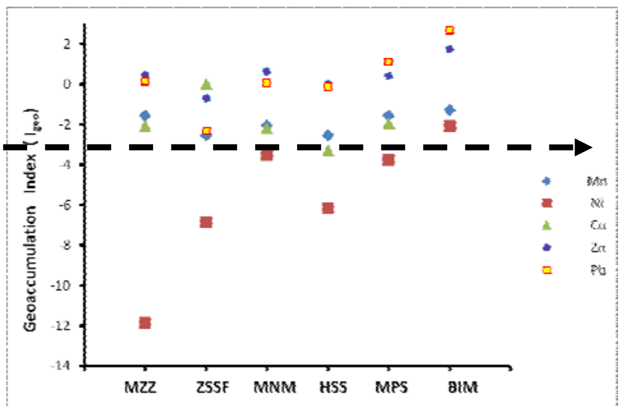

Fig. 5 Geoaumulation indices of heavy metals along the roadside soil.

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