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Accumulation of heavy metal pollutants in soil and vegetation and their effects on soil microbial population on roadsides in Ogbomoso, Nigeria

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Levels of some heavy metals in soil as well as vegetation and their influence on soil microbial population along two highways with contrasting traffic densities in Ogbomoso land, Oyo state, Nigeria were determined. The road with high traffic density had higher Pb, Cd, Cr, and Zn concentrations than the road with low traffic density. The concentrations of the metals in the vegetation obtained from the road with high traffic were generally higher than those observed in vegetation from the road with low traffic. Total viable microbial populations were slightly higher in the soil from high traffic road than in the road with low traffic. However, Total viable microbial population was higher at the 0 - 15cm soil depth than at the 15 - 30cm depth under the two contrasting vehicular densities. The results indicated that high traffic road contained higher heavy metal pollutants in both soil and vegetation than the low traffic, and the microbial population followed the same trend particularly the total viable count. Deposition of these heavy metals in the environment and vegetation in particular could constitute health risk to humans through food chain contamination.

Key words: Total viable count, soil, vegetation, heavy metals, traffic density.

INTRODUCTION

Environmental pollution is always on the increase due to human activities such as agricultural operations, sewage discharge, energy production, smelting, refining, disposal of waste, industrial and vehicular emissions. Emissions of pollutants into the air amounted to the greatest source of heavy metal pollution. Heavy metal pollution of soil enhance plant uptake causing accumulation in plant tissues and eventual phytotoxicity and change in plant community (Ernst, 1996; Zayed *et al.,* 1998; Gimmler et al., 2002,). Heavy metals such as Pb, Cd, Cu, and Zn have been reported to be released into the atmosphere during different operations of the road transport (Zhang et al., 2012; Akbar et al., 2006; Sharma and Prasade, 2010; Atayese et al., 2008).

Zhang et al. (2012) reported engine oil consumption as the largest emission for Cd, tyres wear for Zn, and brake wear for Cu and Pb. Cadmium was reported to biomagnified in *Chromolaena odorata* (Emmanuel and Edward, 2010) Ademoroti (1986) noted that organometalics such as tetraethyl lead, an additive to gasoline (petrol), is an important source of lead in automobile exhaust emission. Soil, vegetation and animals including man act as ‘sinks’ for atmospheric pollutants (Clyde, 1971; Valkovic et al., 1979; Osibanjo and Ajayi, 1980).

Cannon and Bowles (1962) observed that metals in dusts/smoke emitted by vehicles can enter the human food chain through the milk and meat of animals grazing on the plants. From soil and water, all plants have the ability to accumulate heavy metals which are essential for their growth and development. These metals include Mg, Fe, Mn, Zn, Cu, Mo and Ni. Plants also have the tendency to accumulate heavy metals which have no known biological functions; these include Cd, Cr, Pb, Co, Ag, Se and Hg (Hanna and Grant, 1962; Baker and Brooks, 1989). However, excessive accumulation of heavy metals can be toxic to most plants while some are symptomless accumulators and may constitute threats to food chain.

In general, an increase in metal concentration adversely affects soil microbial properties such as respiration rate, enzymatic activity which appears to be very useful indicators of soil pollution (Brooks, 1995; Szili-kovas et al., 1999). Fungi and bacteria constitute the

main component of soil microbial biomass. It has often been stated that fungi are more tolerant of heavy metals as a group than bacteria (Doelman, 1985; Hiroki, 1992).
Therefore this research centers on the assessment of heavy metal content of soil and vegetation and its effects on microbial populations along selected heavy traffic and low traffic density on roadsides of Ogbomoso.

MATERIALS AND METHODS

The study was conducted in Ogbomoso (Longitude 4° 10'E, Latitude 8° 10' N and altitude 213 m asl) Oyo state, Nigeria in July, 2010. The main socio-economic activities along the roads are farming and selling of farm produce. One major and minor road were chosen for the study, Ogbomoso-Oyo as high traffic density (HTD) and Ogbomoso-Ife Odan road as low traffic density (LTD) in Oyo state.

Soil and vegetation samples were obtained from the edge of the roads inwards along three transects of 0 - 10 m, 10 - 20 m and 20 - 30 m. Vegetation along the roads was randomly sampled using systematic random sampling methods with the aid of a 1m by 1m quadrat at the indicated distances. Herbaceous vegetation within the quadrat was cut with stainless steel knife at ground level.

Three spots were sampled within each distance. Soil samples were also collected at similar distances in like manner with soil auger at depths of 0-15 and 15-30cm.All the samples were taken in three replications at about 10km intervals. The samples were transported sterile polythene bags to the laboratory of Department of Agronomy, Ladoke Akintola University of Technology, Ogbomoso. Both soil and vegetation samples were analyzed for Lead (Pb), Cadmium (Cd), Chromium (Cr) and Zinc (Zn)

The soil samples were air dried and sieved with 2mm sieve. The air dried soil sample was weighed for wet digestion. The samples were oven-dried at 70° C to constant weight, ground inside a hammer mill incorporated with 2mm sieve. 2g of the ground samples was then place in crucible and ashed inside furnace at 580°C. The ash was washed into 100ml volumetric flask and wet digested with a mixture of 1:1 perchloric acid and nitric acid. The digested samples were then read from an Atomic Absorption Spectrophotometer (AAS) MILTON ROY 2ID using their respective lamp and wavelengths. Calculation was done using (Peer and Rosen, 1977)

Meter Reading × Slope × Dilution Factor

Standard methods were used to prepare nutrient and potato dextrose agar for estimation of microbial population. One gramme each of the soil samples were measured into the test tube containing 9ml sterile distilled water and serially diluted to dilution factor (10^{-5}) and 1ml of the last dilution was pipette into sterile plate which were incubated at 37°C for NA and PDA incubated at 28°C - 30°C. All plates were incubated inverted wise. Microbial counts were done at 48hrs for NA and 72hrs for PDA in the Petri plates.

Data collected were analyzed using analysis of variance with Statistical Analysis Software (SAS, 1999) and where ANOVA showed significance, means were separated by least significant difference at 5% probability level.

RESULTS

Some of the plant types sampled for chemical analysis are shown in Table 1. Only *Tectona grandis* (Linn.) and *Gmelina arborea* (Roxb) of the plants were not found at low traffic density road.

The results of the heavy metal concentrations in soil, and microbial population along different traffic densities road in Ogbomoso is presented in Table 2. The soil content of Zn and Cr were not significantly different at both high and low traffic density while Pb and Cd were significantly ($p \geq 0.05$) higher in soil at high than low traffic density (Table 2).

Total population was significantly ($p \geq 0.05$) higher at HTD than LTD while the total viable count gave reverse results in which the total fungal population was significant ($p \geq 0.05$) in the low traffic density road than the high traffic density roadside (Table 2).

The result on heavy metal concentrations in soil and microbial populations at different distances along Ogbomoso- Oyo (High traffic) is presented in Table 3. The result showed that Pb and Cd were significantly highest ($p \geq 0.05$) at 0-10 m from the road while 20-30 m had significant ($p \geq 0.05$) lowest heavy metal concentrations. Chromium and Zn were not significantly different at the three distances assessed. Total microbial population and Total fungi count were significantly ($p \geq 0.05$) highest and lowest respectively at 10-20 and 20-30m away from the road (Table 3).

The result on absolute heavy metal concentrations in soil and microbial population at different soil depths along Ogbomoso-IfeOdan (low traffic) roadside is presented in Table 4. The result showed that soil depth at 0-15cm had the highest and significant ($p \geq 0.05$) concentration of Pb, Cd, Cr, and Zn (Table 4). Total microbial population and Total fungi count were higher at 0-15cm than 15-30cm (Table 4).

The result on the heavy metal concentrations in vegetation along roadside with different traffic densities is presented in Table 5. The Table showed that the vegetation samples contained significantly ($p \geq 0.05$) higher amount of Pb and Zn at High traffic density (HTD) than low traffic density (LTD) which in turn had lower concentration of Cr and Cd (Table 5).

The result showed that the heavy metal concentrations in vegetation at different distances from the roadside

Table 1. Identified weed species collected at both high and low traffic density roads.

Name of weed species	High traffic density	Low traffic density
Tectona grandis (Linn.)	+	-
Daniella oliveri (Rolfe)	+	+
Gmelina arborea (Roxb)	+	-
Sida acuta (Burm)	+	+
Gliricidia sepium (Jacq)	+	+
Chromolaena odorata (Linn.)	+	+
Tithonia diversifolia	+	+
Panicum maximum	+	+

+ = Present
- = Absent

Table 2. Mean heavy metal concentrations in soil and microbial populations along roadsides with different traffic densities

Mean heavy metal concentration (mg/kg)					Mean microbial count	
Traffic	**Pb**	**Cd**	**Cr**	**Zn**	**TMP Cfug^{1}(x10^{5})**	**Tfc Cfug^{1}(x10^{5})**
High	6.15	7.08	0.14	4.02	11.14	0.53
Low	4.36	5.20	0.06	2.62	9.97	0.62
LSD	0.54	0.94	0.13	1.36	0.48	0.03

TMP = Total microbial population
Tfc = Total fungi population
Cfug^{-1} = Colony forming unit per gramme

Table 3. Heavy metal concentrations in soil and microbial populations along roadsides with different distances away from the road.

Metals (mg/kg)					Microbial count	
Distance (m)	**Pb**	**Cd**	**Cr**	**Zn**	**TMP Cfug^{1}(x10^{5})**	**Tfc Cfug^{1}(x10^{5})**
0-10	5.70	6.66	0.14	3.41	11.61	0.73
10-20	5.35	6.19	0.08	3.26	10.41	0.56
20-30	4.72	5.56	0.07	3.23	9.65	0.44
LSD	0.25	0.29	0.12	0.22	0.46	0.10

TMP = Total microbial population **Tfc** = Total fungi count **Cfug^{-1}** = Colony forming unit per gramme

Table 4. Absolute value of heavy metal concentrations in soil and microbial populations along roadsides with different soil depths.

Metals (mg/kg)					Microbial count	
Depth (cm).	**Pb**	**Cd**	**Cr**	**Zn**	**TMP Cfug^{1}(x10^{5})**	**Tfc Cfug^{1}(x10^{5})**
0-15	5.99	6.87	0.10	3.52	11.29	0.76
15-30	4.52	5.40	0.09	3.12	9.82	0.39
LSD	0.20	0.24	0.099	0.18	0.37	0.08

Tvc = Total viable count **Tfc** = Total fungi count **Cfug^{-1}** = Colony forming unit per gramme

were not significantly ($p \geq 0.05$) different from one another, except Chromium (Cr) which was significantly ($p \geq 0.05$) higher at 20 - 30m distance from that of 0 - 10m (Table 6).

A comparison of the average heavy metal content in vegetation revealed that HTD recorded higher metal concentration than LTD. At HTD road, Pb (4.00 ± 1.53mg/kg) and Cd (4.34 ± 1.67mg/kg) were higher at 10 - 20m than 0 - 10m and 20 - 30m from the road. Chromium (0.15 ± 0.01mg/kg) was higher at 20-30m than the other distances closer to the road. Zinc was highest (4.10 ± 0.01mg/kg) at 0 - 10m from the road followed by 20 - 30m and lowest (3.90 ± 0.01mg/kg) at 20 - 30m from the road (Table 7).

In Table 8 the soil concentration of heavy metals along high traffic density road was averagely higher than that of LTD. Table 8 further indicated that concentration of all the metals in the soil decreased with increasing distances at the HTD road. Lead and cadmium did not follow the same trend at LTD road.

Total microbial population was higher at HTD than LTD while the reverse trend was observed with Total fungi

Table 5. Heavy metal concentrations in vegetation along roadsides with different Traffic densities.

Traffic	**Metals (mg/kg)**			
	Pb	**Cd**	**Cr**	**Zn**
High	3.94	4.29	0.13	3.98
Low	3.38	4.48	0.06	2.74
LSD	0.32	0.25	0.09	0.79

Table 6. Heavy metal concentrations in vegetation along roadsides with different distances from the edge of the road.

Distance(m)	**Metals (mg/kg)**			
	Pb	**Cd**	**Cr**	**Zn**
0-10	3.78	4.64	0.08	3.50
10-20	3.39	4.07	0.09	3.26
20-30	3.82	4.46	0.12	3.33
LSD	1.05	1.09	0.04	0.3

Table 7. Heavy metal concentration in vegetation along roadsides with different distances from the road.

Level of traffic and distance	**Metals (±SD)(mg/kg)**			
	Pb	**Cd**	**Cr**	**Zn**
Ha	3.85±0.40	4.23±0.32	0.12±0.05	4.10±0.01
Hb	4.00±1.53	4.34±1.67	0.13±0.02	3.90±0.01
Hc	3.98±0.87	4.31±0.88	0.15±0.01	3.95±0.15
La	3.70±0.50	5.05±0.75	0.03±0.01	2.90±0.20
Lb	2.79±0.39	3.79±0.55	0.05±0.02	2.62±0.22
Lc	3.66±1.13	4.60±1.29	0.08±0.04	2.71±0.90

Key: **H** = high traffic **L** = low traffic **a** = 0-10m **b** = 10-20m **c** = 20-30m **SD =** Standard Deviation

count in which LTD road had higher Total fungi count than HTD (Table 8).

The average heavy metal concentration in the soil shown in Table 9 indicated that 0 - 15 cm soil depth had higher concentrations of heavy metals than 15 - 30cm depth at both HTD and LTD roads. Generally the metal concentration in the soil at LTD was lower than HTD. Microbial population decreased generally from the edge of the road to the inward part. Thus, 20 - 30m from both HTD and LTD roads recorded lowest microbial population. Table 9 showed further that 0-15 cm soil depth had higher concentrations of heavy metals than 15 - 30cm depth at both HTD and LTD roads.

DISCUSSION

The results obtained indicated increasing heavy metal pollutants with increasing traffic density and that heavy metal concentrations decreased with increasing distance away from the edge of the roadside inward. This result could be corroborated by that of Haygarth and Jones (1992) who reported decrease metal concentrations with increasing distance from the road. He observed that this phenomenon might be due to heavy metals emitted from vehicle exhausts in particulate forms which are forced to settle under gravity closer to the edge of the road. The top 0 - 15cm of soil contained higher metal content than 15 - 30cm soil depth. This is in line with the results of many authors who did similar research (Nyangababo and Hamya, 1986; Amusan *et al*., 2003).

Nyangababo and Hamya (1986) attributed high heavy metal concentration of the topsoil to high organic matter status responsible for fixation of metals in soils. Drive time, peak hour, take away delivery and so on contribute to car movements. It is important to note that cars may get us from places to places but they also cause serious environmental pollution. The emissions from petrol, diesel and alternative fuel engines including benzene, lead, organic compounds, carbon monoxide, oxides of nitrogen, un-burnt hydrocarbons, sulphur dioxide, and other suspended fine particulate matter like smoke, metals (Cd, Co, Cu, Zn, etc.) as well as inert dust (Gaighate and Hasan, 1999).

Vegetation along high traffic road contained higher concentrations of heavy metals than low traffic density. However, irregular distribution of the metals was observed along the gradient from the road edge inwards. These results agreed with that of Voegborlo and Chirgawl (2007) whose report clearly defined gradients of lead

Table 8. Heavy metal concentration and microbial population along roadsides with different distances from the road.

Level of traffic and distance	Metals (±SD)(mg/kg)				Microbes	
	Pb	Cd	Cr	Zn	TMP Cfug^{-1} (x10^5)	Tfc Cfug^{-1} (x10^5)
Ha	6.93±1.00	7.89±1.29	0.23±0.31	4.07±0.26	2.12±1.03	0.62±0.17
Hb	6.18±0.84	7.18±1.12	0.10±0.03	4.03±1.05	11.10±0.93	0.05±0.11
Hc	5.34±0.72	6.15±0.62	0.08±0.05	3.96±1.13	10.20±0.79	0.48±0.16
La	4.47±1.19	5.42±1.27	0.06±0.01	2.74±0.31	11.1±0.88	0.83±0.29
Lb	4.51±0.83	5.21±0.90	0.06±0.02	2.62±0.36	9.72±1.00	0.62±0.40
Lc	4.11±0.61	4.97±0.66	0.06±0.02	2.50±0.34	9.10±0.81	0.40±0.22

Key: **H** = high traffic **TMP** = Total Microbial Population
L = low traffic **Tfc** = Total fungi count
a = 0-10m **Cfug**$^{-1}$ = Colony forming unit per gramme
b = 10-20m **c** = 20-30m **SD =** Standard Deviation

Table 9. Heavy metal concentrations in soil and microbial population along roadsides with different depths and distances from the road.

Soil depth and distance	Metals (±SD)(mg/kg)				Microbes	
	Pb	Cd	Cr	Zn	TMP Cfug^{-1} (x10^5)	Tfc Cfug^{-1} (x10^5)
Had1	7.80±0.40	9.00±0.30	0.36±0.47	4.23±0.05	13.03±0.21	0.77±0.06
Had2	6.06±0.30	6.78±0.61	0.10±0.01	3.91±0.31	11.20±0.27	0.47±0.06
Hbd1	6.83±0.21	7.70±0.63	0.07±0.01	4.16±1.02	11.9±0.46	0.60±0.00
Hbd2	5.53±0.67	6.67±1.39	0.12±0.02	3.91±1.29	10.30±0.10	0.40±0.00
Hcd1	5.97±0.28	6.68±0.28	0.05±0.01	4.10±1.06	10.9±0.10	0.57±0.21
Hcd2	4.70±0.13	5.62±0.25	0.12±0.06	3.82±1.43	9.50±0.30	0.40±0.00
Lad1	5.55±0.15	6.57±0.27	0.05±0.01	2.98±0.18	11.57±0.35	1.07±0.15
Lad2	3.39±0.13	4.28±0.11	0.06±0.01	2.50±0.20	10.63±1.05	0.60±1.0
Lbd1	5.23±0.27	5.89±0.51	0.05±0.01	2.91±0.18	10.57±0.25	0.77±0.15
Lbd2	3.79±0.31	4.52±0.59	0.07±0.02	2.32±0.18	8.87±0.55	0.27±0.06
Lcd1	4.58±0.28	5.40±0.08	0.04±0.01	2.76±0.18	9.77±0.21	0.60±0.00
Lcd2	3.64±0.44	4.54±0.73	0.07±0.02	2.24±0.24	8.43±0.50	0.20±0.00

Key: **H** = high traffic **TMP** = Total microbial population
L = low traffic **Tfc** = Total fungi count
a = 0-10m **Cfug**$^{-1}$ = Colony forming unit per gramme
b = 10-20m **d1** = 0-15cm depth
c = 20-30m **d2** = 15-30cm depth
SD = Standard Deviation

contamination beside roadways, and less-defined gradients of other metals including cadmium, chromium, copper, nickel, vanadium, and zinc. Phytotoxicity of heavy metals and other particles emitted from auto-exhaust have been shown to accumulate and may cause damage and death of plant species growing along road side (Alfani et al., 1996).

Total fungi count was higher at low traffic density where heavy metals were low than high traffic density where total microbial population were higher. It has been reported that a neutral soil may contain high levels of Mn, Al or Pb without any sign of toxicity to microorganisms whereas toxicity may develop with certain organisms at much lower metal concentrations in acid soils (Marschner and Kalbitz, 2003; Utgikar et al., 2003). Rabia and Tansneem, (2007) reported that lead and silver were found to be toxic for the growth of microorganisms. Toxic effects of heavy metals on micro-organisms manifest in numerous ways such as decrease in litter decomposition and nitrogen fixation, less efficient nutrient cycling (Baath, 1989). As the metals are immobile in the soil, they accumulate in top soil thereby endangering crops, plants and microbial population and composition. Food chain may be contaminated as organisms interact majorly in terms of energy transfer from producers to consumers (Athar and Vohora, 1995). Continuous deposition of these heavy metals indicates potential health risk for human through the food chain. Exposure to heavy metals is normally chronic due to transfer to food chain (USDA, 2000).

The pollutants are known to damage lung tissues and cause asthma and other lethal diseases. Chronic exposure to metals at a high level caused chronic toxicity effects such as hypertension in individuals exposed to lead and renal toxicity in individuals exposed to cadmium. Children and developing fetuses appear to be particularly vulnerable to the neurotoxic effects of lead. It has been demonstrated that low-level lead exposure in children less than five years of age with blood lead levels in the 5-25µg/dL range results in deficits in intellectual development as manifested by lost intelligence quotient points (Banks et al., 1997).

The heavy metals can impair important biochemical processes posing a threat to human health (Akbar et al., 2006; Ayodele and Oluyomi, 2011). It has been reported that prolonged consumption of sub-lethal concentrations of heavy metals through food may lead to their chronic accumulation which hinder proper functioning of the kidney and liver of humans thereby causing disruption of numerous biochemical processes, leading to cardiovascular, nervous, kidney and bone diseases (Jarup; 2003, WHO; 1995, Steenland and Bufett; 2000, Radwan and Salama; 2006).

The loss of calcium caused by cadmium's effects on the kidney can be severe enough to lead to weakening of bones, "itaitai" disease, an epidemic of bone fracture in Japan from gross cadmium contamination of rice stocks, has been shown to happen in more subtle fashion among a general community living in area of relatively modest cadmium contamination (Staessen, 1999). Chromium toxicity stems from its tendency to be corrosive and to cause allergic reactions. It is a carcinogen, particularly of the lung through inhalation (Howard, 2002).

The European Union ranged Cd in soil of 0-1mg/kg indicated non-contaminated soil, 1-3mg/kg indicated slight contamination and 3-10mg/kg indicated a contaminated soil. Thus, both the high and low traffic density roads assessed in this study were contaminated in terms of cadmium. The results of this study when compared with the WHO/FAO standard lower limits of Pb (0.3mg/kg), Cd (0.2mg/kg) and Cr (0.05mg/kg) indicated that both the soil and vegetation along both roads were contaminated with heavy metals.

Heavy metal accumulation by plant tissues, its presence in the soil persistently or its presence in ground waters is not a healthy sign for the environment. Controlling air pollution from motor vehicle is essential if the adverse effects will be nip in the bud (EPA, 2012). Proper maintenance of vehicles and regulation of truck emission control systems will not only limit harmful emissions but will also improve fuel use efficiency and extend the life of vehicles.

Zhang et al. (2012) findings indicate that trees growing linearly along roadways can effectively reduce the heavy metals' concentrations in the roadside farmland. The results of this research show that distances along roadside within 30m from the roads were heavy metal-laden due to vehicular emission and as such contaminate the soil and vegetation and adversely affect microbial population.

Conclusively, a red alert is given to consumers of agricultural products from farms close to these roads in that there should be caution in consuming such products to avoid health related complications.

REFERENCES

Ademoroti CMA (1986). Levels of heavy metals on bark and fruit of trees in Benin-city, Nigeria. *Int. J. Environ. Pollut.* 11: 241-253.

Akbar KF, Hale WHG, Headley AD, Athar M (2006). Heavy Metal Contamination of Roadside Soils. Soil Water Res., 1(4):158-163.

Alfani A, Maisto G, Iovieno P, Rutigliano FA, Bartoli G (1996). Leaf contamination by atmospheric pollutants as assessed by elemental analysis of leaf tissue, leaf surface deposit and soil. *J. Plant Physiol*., 148: 243-248.

Amusan AA, SB Bada, AT Salami (2003). Effect of Traffic Density on Heavy Metal Content of Soil and vegetation along Roadsides in Osun State, Nigeria. *West African J. Appl. Ecol.,* 4: 107-113.

Atayese MO, Eigbadon AI, Oluwa KA, Adesoduni JK (2008). Heavy Metal Contamination of Amaratus grown along major highways in Lagos, Nigeria. Afr. Crop Sci. J., 16(4): 225-235.

Athar M, Vohora SB (1995). Heavy metals in soils. Blackie Academic and Professional, New York (pub) p.216.

Ayodele JT, Oluyomi CD (2011). Grass contamination by trace metals from road traffic. J. Environ. Chem. Ecotoxicol., 3(3): 60-67.

Baath E (1989). Effects of heavy metals on microbial processes and population. *Air Soil Pollut.* 47: 355-379.

Baker AJM, Brooks RR (1989). Terrestrial higher plants which hyper accumulate metallic Elements – A review of their distribution , ecology and phytochemistry. *Biorecovery* 1: 81-126.

Banks EC, Ferreti LE, Shucard DW (1997). Effects of low-level lead exposure on cognitive function in children: A review of behavioral, neuropsycological and biological evidence. *Neurotoxicology* 18: 237-281

Brooks PC (1995). The use of microbial parameters in monitoring soil pollution by heavy metals. *Biol. Fertil. Soils*, 19: 269-279.

Cannon HL, Bowles JM (1962). Contamination of vegetables by tetraethyl lead. *Science, N.Y.,* 137: 765-766.

Clyde AH (1971). Vegetation: A sink for atmospheric pollutants. *J. Air Pollut. Control Ass*. 21: 341.

Doelman P (1985). Resistance of soil microbial communities to heavy metals, p. 369-384. Inv. Jensen, A.Kjoller and L.H. Sorensen (ed.), Elsevier, London, United Kingdom.

Emmanuel OF, Edward OO (2010). Evaluation of the status of heavy metal pollution of soil and plants (*Chromolaena odorata*) of Agbabu Bitumen Deposit Area, Nigeria. *American-Eurasian J. Sci. Res.,* 5 (4): 241-248. ISSN1813-6785. ©IDOSI Publications,2010.

Environmental Protection Agency (EPA) 2012. Controlling air pollution from motor vehicles. Department of Environmental Conservation U.S.A. Environmental Protection Agency. www.dec.ng.gov/chemical/8910.html.

Ernst WHO (1996). Bioavailability of heavy metals and decontamination of soil by plants. *Appl. Geochem.,* 11*:* 173-167.

Gaighate DG, Hasan MZ (1999). Ambient lead levels in urban areas. *Brill. Environ. Contamination and Toxicol*., 62: 403-408.

Gimmler H, Carandang J, Boots A, Reisberg E, Woitke M (2002). Heavy metal content and distribution within a woody plant during and after seven years continuous growth on municipal solid waste (MSW) bottom slag rich in heavy metals. *J. Appl. Bot.,* 76: 203-217.

Hanna WJ, Grant CL (1962). Spectrochemical analysis of foliage of certain trees and ornamentals for 23 Elements. *Bull. Torrey Bot. Club* 89: 293-302.

Haygerth PM, Jones KC (1992). Atmospheric deposition of metals to Agricultural surfaces. In Biogeochemistry of trace metals. Eds. D.C. Adviano. Pp 249-276. CRC Press, Boca Raton.

Hiroki M (1992). Effects of heavy metal contamination on soil microbial population. *Soil Sci. Plant Nutr.,* 38: 141-147

Howard Hu (2002). Human Health and Heavy Metal Exposure: In Life Support: the Environment and

Human Health. Ch. 4, Michael McCally (ed), MITpress.

Jarup L (2003). Hazards of heavy metal contamination. Br. Med. Bull., 68: 167-182.

Marschner B, Kalbitz K (2003). Control of bioavailability and biodegradation of dissolved organic Matter in soils. *Geoderma.,* 113(3-4), 211-235.

Nyangababo JT, Hamya JW (1986). The deposition of lead, cadmium zinc and copper from motor traffic on *Brachiaria enimi* and soil along a major Bombo road to Kampala City. *Int. Envir. Stud.* 27: 115-119.

Osibanjo O, Ajayi SO (1980). Trace metal levels in tree barks as indicators of atmospheric pollution. *Envir. Int*., 4: 239-244.

Peer JR, Rosen WG (1977). Lead and Cadmium content of urban garden vegetable trace subst. Environ. Health, 11: 399-405.

Rabia Ashraf, Tansneem Adam Ali (2007). Effects of heavy metals on soil microbial community and Mung beans seed germination. *Pak. J. Bot.,* 39(2): 629-636.

Radwan MA, Salama AK (2006). Market basket survey for some heavy metals in Egyptian fruits and vegetables. *Food Chem. Toxicol*., 44: 1273-1278.

Sharma S, Prasade FM (2010). Accumulation of Lead and Cadmium in Soil and Vegetable Crops along Major Highways in Agra (India). J. Chem., 7(4):1174-1183.

Staessen JA, Roels HA, Emelianov D, Kuznetsova T, Thijs L, Vangronsveld J (1999). Environmental exposure to cadmium, forearm bone density, and risk of fractures: Prospective population study. Public Health and Environmental Exposure to Cadmium (PheeCad) Study Group. *Lancet* 353: 1140-1144.

Steenland K, Boffetta P (2000). Lead and cancer in humans: where are we now? Am. J. Ind. Med., 38: 295-299.

Szili-Kovacs T, A Anton, F Gulyas (1999). Effect of Cd, Ni, and Cu on some microbial properties of a calcareous Chernosem soil. (Ed.): J. Kubat. In: Proc. 2nd Symp on the "Pathways and Consequences of Dissemination of Pollutants in the Biosphere" *Prague*, 82-102.

United State Department of Agriculture (USDA) 2000. Heavy metal soil contamination. Soil Quality – Urban Technical Note, No. 3 NRCS September, 2000.

Utgikar VP, Tabak HH, Haines JR, Govind R (2003). Quantification of toxic inhibitory impact of copper and zinc on mixed cultures of sulphate reducing bacteria. *Biotech. Bioeng.,* 82 (3), 306-312.

Valkovic V, Rendic D, Biegert EK (1979). Trace element concentration in tree rings as

indicators of environmental pollution. *Environmentalist* 2: 27.

Voegborlo RB, MB Chirawl (2007). Heavy metal accumulation in roadside soil and vegetation along a major highway in Lybia. *J. Sci. and Technol.,* 27(3): 1-12.

WHO (1995). *Lead environmental health criteria*. Geneva: World Health Organization, p. 165.

Zhang F, Yan X, Zeng C, Zhang M, Shrestha S, Devkota LP, Yao T (2012). Influence of Traffic Activity on Heavy Metal Concentrations of Roadside Farmland Soil in Mountainous Areas. Int. J. Environ. Res. Public Health 9(5): 1715-1731.

Zeyed A, Lytle CM, Qian JH, Terry N (1998). Chromium accumulation, translocation and chemical Speciation in vegetable crops. *Planta* 206: 293-299.