A Case Study of Heavy Metal Concentrations in Soil and Leafy Vegetables from Roadside Gardens in Lagos, Nigeria

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Abstract
The concentrations of lead, cadmium and copper in soil and leafy vegetable from roadside gardens in Lagos were investigated. Soil and plant samples were collected from gardens along three major highways where roadside farming is a common practice at a distance of 10 meters away from the roadside. The control soil samples were collected 200 meters away from the roadside at each of the three locations. The concentrations of the three metals in the samples were measured using Flame Atomic Absorption Spectrophotometry (FAAS). The concentration of lead was the highest in soil and plant samples from the roadside gardens at the three locations, and varied from 21.35 ± 0.18 to 24.79 ± 0.22 mg kg^{-1} in garden soils, while its mean levels in the aerial portion of the vegetable varied from 14.36 ± 0.40 to 15.22 ± 0.30 mg kg^{-1} dry wt. The control soils however had significantly low levels of lead which varied from 1.89 ± 0.02 to 3.43 ± 0.09 mg kg^{-1}, while the mean levels of copper ranged from 6.92 ± 0.02 to 7.36 ± 0.01 mg kg^{-1}. Concentrations of the three metals in the vegetable were more in the root tissue than the shoot. It was established in this study that the high levels of these metals in soil and plant samples from the roadside gardens was directly related to the vehicular traffic on the highways at these study sites.

Keywords: *Roadside gardens; Leafy vegetable; Heavy metals; Pollution; Accumulation; Safety*

Introduction

Heavy metal contamination in soil-water-plant ecological system is of great importance because of the possible influences on the food chain and the potential health hazards for livestock and humans. Soils near highways with high density of traffic are polluted by heavy metals emitted from automobiles (Onianwa and Adoghe 1997). These metals are released into the roadside environment during different operations of road transport such as transporting industrial chemicals and other materials, combustion of gasoline, wear-and-tear of tyres, and vehicle engines, leakages of lubricating oil and corrosion of metal components. A great part of these metal pollutants are deposited on the road and adjacent soil from where they are transported farther away into the environment either through the air or rain runoff thereby exposing the roadside soil and vegetation to the risk of heavy metal contamination.

Lagos is densely populated and the number of motor vehicles in this city is quite high, consequently, emission from automobiles which contributes to elevated levels of contaminants in the environment is a common phenomenon. The problem is further compounded by the fact that Nigeria is a third world country and a major importer of used vehicles from Europe and North America. Most of these vehicles are old and as a result emit gases and particles that pollute the air, soil and water.

It is a common practice among the Hausa settlers in Lagos to maintain roadside gardens where they cultivate leafy vegetables that serves as their source of income. These gardens are quite common at some specific locations along Mile 2 – Badagry, Lekki – Epe, and Mile 12 – Ikorodu highways. Due to the peculiarity of the locations of these gardens, heavy metals may enter the food chain as a result of their uptake by these vegetables. Hence, determination of heavy metals in soil and plant samples from roadside gardens is very important. Some of these metals have significantly toxic effects on human health. It is known that lead (Pb) has serious health effects on humans and this include anemia and neurological disorders (Flora 2002). Cadmium (Cd) is a toxic metal and it is known to cause renal, pulmonary, hepatic, skeletal and reproductive disorders (Nordberg 2003). Copper (Cu) is an essential element that is required by most living organisms in minute quantities, and become toxic when its concentration in a living system exceed the threshold limit. Kidney and liver damage are some of the health effects associated with copper toxicity in humans (Yang *et al*. 2002).

Considering the health effects of these metals, it is important to monitor the levels of lead, cadmium and copper in the environment, especially in areas where they can easily enter the food chain (as in the case of roadside gardens). Determination of heavy metals in vegetables provides valid information about their quality in terms of toxicology and nutritional values (Carlosena *et al*. 1999). Although, few studies have been conducted to evaluate the concentration of toxic heavy metals in roadside vegetables here in Nigeria (Onasanya *et al*. 1993; Olajire and Ayodele 1997; Fakayode and Olu-Owolabi 2003), no such study has been done in Lagos, the most populous city in Nigeria.

It is therefore the aim of this study to determine the levels of lead, cadmium, and copper in roadside garden soils and vegetables in Lagos, and to assess the safety level of the current practice of growing leafy vegetables for commercial purpose on lands adjacent to highways.

Materials and Methods

Collection of samples

The three sites selected for this study, based on the density of traffic and the presence of roadside gardens, were Mile 2 – Badagry (BDG), Lekki – Epe (LEK), and Mile 12 – Ikorodu (KRD). Each of these highways carries average of 10^5 vehicles per day. At each study site, three samples each of soils and vegetables (*Amaranthus hybridus*) were collected from the garden at a distance of 10 meters away from the edge of the main road. The soil samples were taken from the upper soil layer of 0-10 cm, while vegetables of the same age were carefully uprooted and wrapped in labeled paper bags before taking them to the laboratory. The soil samples that served as the control were collected from each of the corresponding sites at a distance of 200 m from the edge of the main road.

Sample preparation and analyses

The pH and electrical conductivity (EC) of the soil samples were determined by shaking 5 g of soil in 50 ml distilled water overnight using mechanical shaker. After filtration through Whatman filter paper, the parameters were measured using the pH and the Conductivity meters (Fisher Accumet Excel XL20).

For metal quantification, soil samples were air-dried, ground in porcelain mortar to pass through 2 mm sieve. After that, 1.0 g of soil was weighed into 100 ml conical flask and 10 ml of HNO_3/H_2O_2 mixture (2/1) was added and left to stand overnight. Thereafter, the flask was heated on a hot plate at 70 ^oC for 1 hr and allowed to cool. Filtration through Whatman filter paper was done into a 100 ml volumetric flask and made up to the mark with distilled water. The filtrate was analyzed for total Pb, Cd, and Cu using Flame Atomic Absorption Spectrophotometry (Perkin Elmer AAnalyst 100). The equipment was calibrated with standards of the metals, while blanks were used for quality control (Chirenje *et al*. 2003).

Harvested vegetables were thoroughly washed in a running tap water to remove adhering soil particles. They were separated into root and shoot before placing them separately into labeled paper bags and oven dried at 80 ^oC for 2 days. Dried plant materials were ground in porcelain mortar. Thereafter, 1.0 g of the ground sample was weighed into a 50 ml beaker and 10 ml of concentrated HNO_3/H_2O_2 mixture (2/1) was added and allowed to stand overnight. It was then heated to near dryness and allowed to cool. Then, 20 ml of distilled water was added and thoroughly mixed and then filtered into 50 ml flask and made up to the mark with distilled water. The metal contents (Pb, Cd, and Cu) were then quantified using FAAS. The optimum conditions for FAAS are given in Table 1. Unless otherwise stated, all chemicals used were of high purity reagent grade.

Table 1. Operating parameters for FAAS

Parameters	Pb	Cd	Cu
Wavelength (nm)	217	229	324.8
Acetylene flow rate (l/min)	6.0	6.0	6.0
Air flow rate (l/min)	4	4	4
HCl current (mA)	9	4	4
Slit (nm)	0.5	0.5	0.5

Statistical analysis: Data were analyzed using one way analysis of variance (ANOVA) with differences determined using Duncan's multiple comparisons test. Differences were considered to be significant at a probability of 5% ($p = 0.05$).

Results and Discussion

The physicochemical properties of soils from the different study sites as well as their corresponding controls are presented in Table 2. The garden soils generally had a higher pH values than their corresponding control soils in all the study sites. The garden soil at BDG had the lowest pH value of 7.2 while LEK and KRD had pH values of 7.4. In the control soils however, the minimum pH value of 6.8 was observed at BDG while LEK gave the maximum value of 7.1. The results of electrical conductivity indicated higher conductivity in the control soils compared to the garden soils. The LEK garden soil had the maximum conductance value of 116 µs/cm while KRD had the lowest value of 111 µs/cm. The maximum value of 123 µs/cm was also observed for LEK control soil. The slight difference in pH values between the garden and the control soils could be attributed to the kind of inorganic fertilizers applied to the garden during vegetable cultivation, while the high EC observed in LEK soils could be attributed to the proximity to the ocean which generally contains high salt content.

Table 2. Physicochemical property of soils from roadside gardens and the control sites.

Site	pH		EC(µs/cm)	
	Garden soil	Control	Garden soil	Control
BDG	7.2	6.8	113	120
LEK	7.4	7.1	116	123
KRD	7.4	6.9	111	118

A comparison of the heavy metal contents among the study sites implicated automobiles as the source of contamination. Data from the present study showed that the concentration of metals decreased with distance from the roadside. In all the study sites, the metal contents in the garden soils were consistently higher than the control soils, with Pb and Cd representing the most and the least concentrated metals respectively. Figure 1 shows the results of heavy metal analysis of the BDG soil samples. The highest value of 24.79 ± 0.22 mg $kg^{-1}$was observed for Pb, while 2.36 ± 0.18 mg kg^{-1} was recorded for Cd. These values were significantly higher than 3.43 ± 0.09 and 0.45 ± 0.01 mg kg^{-1} observed for Pb and Cd respectively in the control soil. The metal contents in LEK and KRD garden soils also followed the same pattern, the order was Pb > Cu > Cd (Figures 2 and 3). This might be a confirmation that the contamination of the samples by these metals was caused by heavy traffic around the sites. The concentration of Pb, the most important roadside pollutant in soil was found to be highest in all the study sites. This is explainable since in the past decades, there has been a widespread use of Pb-based antiknock agents such as tetraethyl lead (TEL) used as additives in gasoline used to power most vehicles with internal combustion engines.

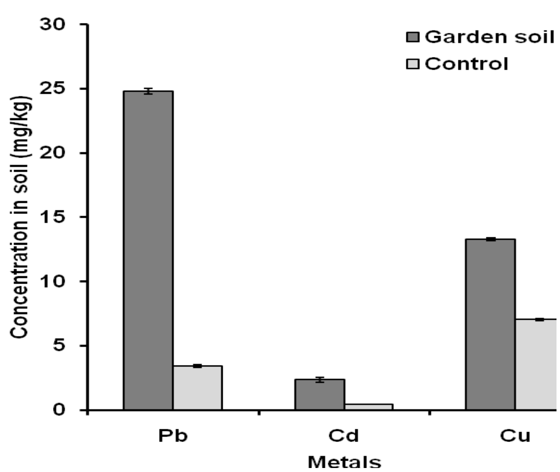

Figure1. Metal concentration in soil from roadside garden at Abule Ado area along Mile 2 – Badagry highway (BDG).

Due to the increasing awareness about the problems associated with Pb, the use of leaded gasoline has been decreasing in recent years especially in developed nations. Nigeria as a developing nation has not really done much in this regard, as Pb deposit in roadside soils is high compared to other metals. In addition to this, the high density of vehicular traffic in Lagos metropolis has contributed immensely to Pb emission and pollution of air, soil and water in the city and its environs. The Pb content of the garden soils from the study sites falls within the range of Pb in roadside soils from other cities in Nigeria earlier reported by other workers (Fakayode and Olu-Owolabi 2003; Olajire and Ayodele 1997; Ogunfowokan *et al.* 2009).

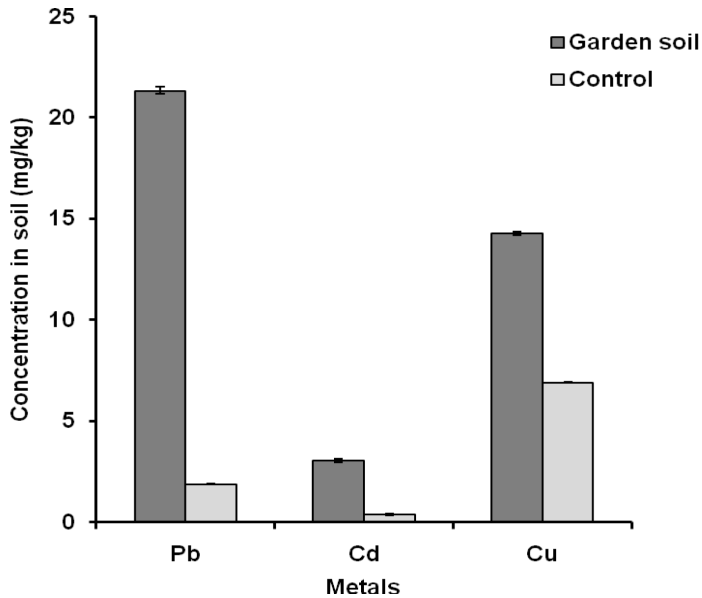

Figure 2. Metal concentration in soil from roadside garden at Ajah, along Lekki – Epe highway (LEK).

Cadmium deposition into the roadside environment have been related to the composition of gasoline, lubricating oil, vehicle tyres, as well as industrial materials transported on the road to various destinations (Lagerwerff and Specht 1970). Soils from all the study sites had Cd contents in the range of 2.06 ± 0.03 to 3.04 ± 0.08 mg kg^{-1}. These values were significantly higher than 0.38 ± 0.05 and 0.45 ± 0.01 mg kg^{-1} observed in the control soils. The results of this study showed that Cd pattern among the sites is not significantly different from the Pb pattern. The concentration of Cd in the garden soil was higher than the control soil suggesting that vehicular emission played a major role in the levels of Cd in the roadside soils.

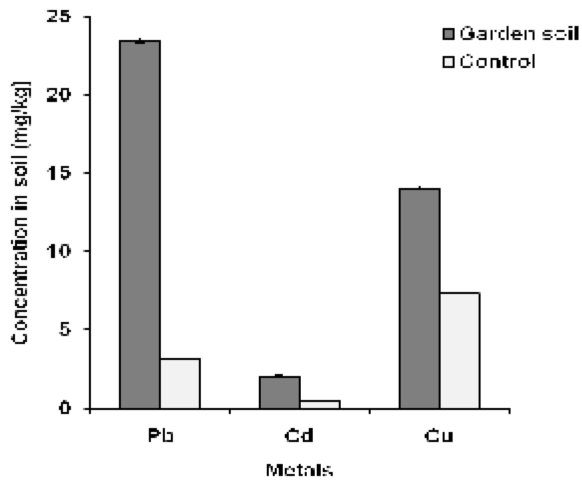

Figure 3. Metal concentration in soil from roadside garden along Mile 12 – Ikorodu highway (KRD).

In this study, it was observed that the overall level of copper in the garden soils from the three sites ranged from 13.28 ± 0.12 to 14.28 ± 0.10 mg kg^{-1}. It was also observed that the background levels of Cu in the control soils were relatively high compared to Pb and Cd. This difference could be that other sources of contamination apart from vehicular emission exists, or it could be that airborne dust particles carrying Cu moved further away from the roadside before deposition on the surrounding soils.

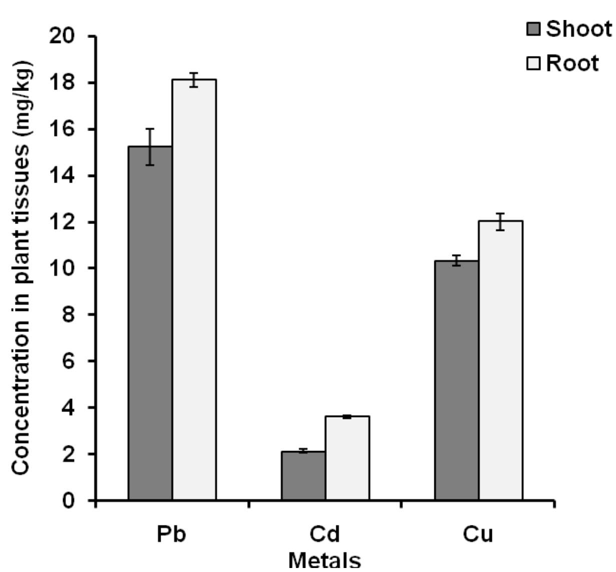

Figure 4. Metal concentration in *Amaranthus hybridus* harvested from roadside garden at Abule Ado area, along Mile 2 – Badagry highway (BDG).

The concentration of Pb, Cd and Cu in the plant samples from the three study sites are as presented in Figures 4, 5, and 6. As expected, the metals accumulated more in the roots than in the shoots. There was a positive correlation between the soil metal levels and the tissue concentrations. The order of metal accumulation in the plant tissue was Pb > Cu > Cd regardless of the part of the plant analyzed.

The metal levels in the shoot of the vegetable samples lies between 14.36 ± 0.47 and 15.22 ± 0.77 mg kg^{-1} for Pb, 1.22 ± 0.24 and 2.13 ± 0.08 mg kg^{-1} for Cd, and 10.33 ± 0.23 and 11.63 ± 0.33 mg kg^{-1} for Cu. Plants absorbs metals via the roots and part of the absorbed metals are translocated to the aerial parts of the plants. The mobility and bioavailabilty of heavy metals are controlled by soil factors such as pH, redox potential, organic matter, and the chemical form or species of the metals (Andriano 1986). Airborne particles of heavy metals, a major source of metal pollution in highway environment, are also readily taken up by plants through foliage (Singh *et al.* 1995). Thus, the metals that accumulated in the vegetable tissues from the roadside gardens in this study probably could have been taken up by the plants through the roots and the leaves.

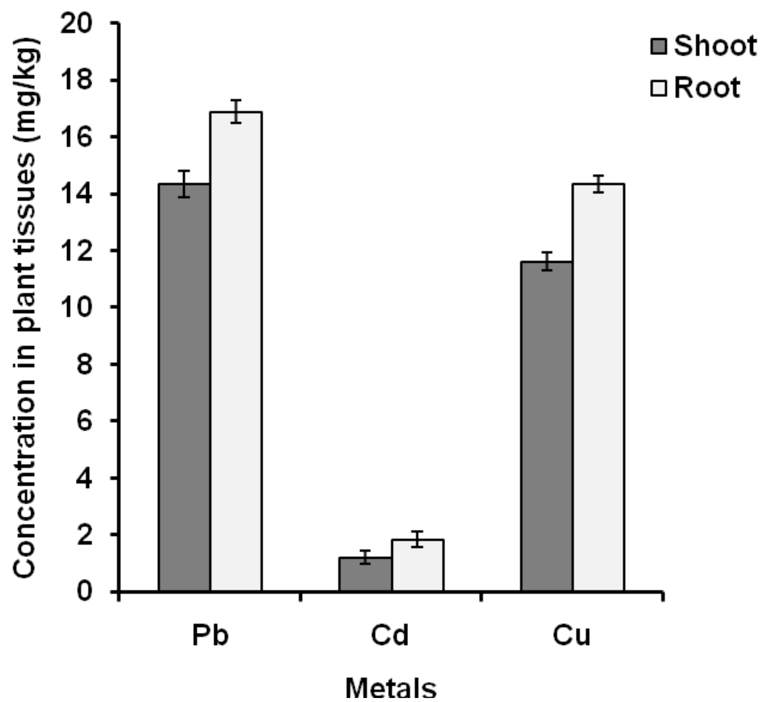

Figure 5. Concentration of metals in *Amaranthus hybridus* harvested from a roadside garden at Ajah, along Lekki - Epe highway (LEK).

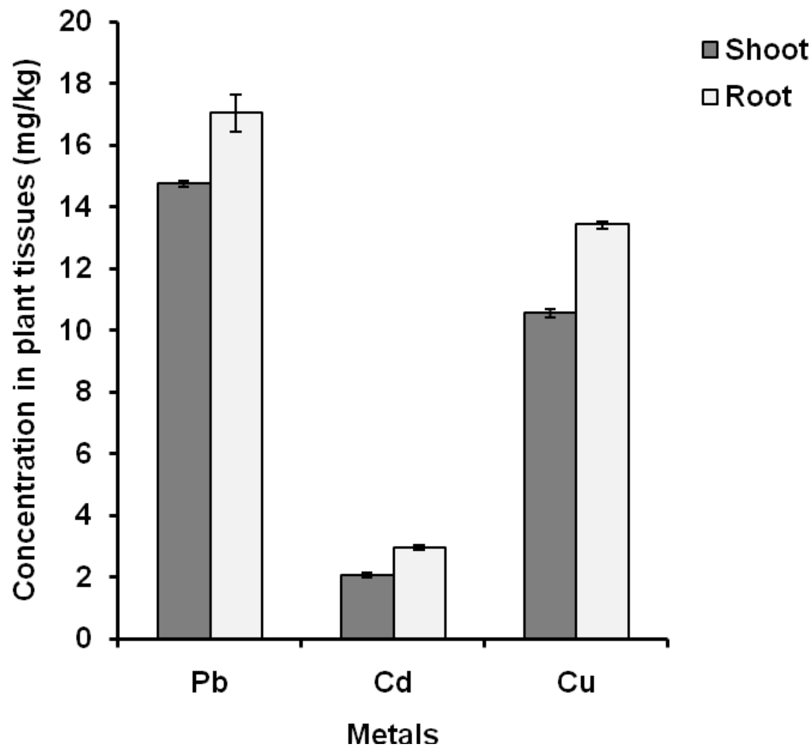

Figure 6. Concentration of metals in *Amaranthus hybridus* harvested from a roadside garden along Mile 12–Ikorodu highway (KRD).

The results of this study showed that heavy metals (Pb, Cd, and Cu) were present in roadside garden soils and vegetables in high enough concentrations to cause health problems in humans and animals. This agrees with Fakorede and Olu-Owolabi (2003). The concentrations of these metals in the edible part of the vegetables were higher than the permissible limits recommended by World Health Organization (2005). The permissible limits for Pb, Cd and Cu were given as 0.001, 0.003 and 0.01 mg/kg respectively. There was a valid indication that vehicles on these highways were mostly responsible for the buildup of these metals in soil and plant tissues within the highway vicinity through emissions and wears of component parts. Consumption of the vegetables from these study sites by animals and humans pose a serious health implication. Adverse health effects like diarrhea, liver and kidney damage have been associated with Cu (Yang *et al.* 2002). Cadmium could also be shown to be associated with occurrences of Itai-Itai, a disease under which patients show a wide range of symptoms such as: low grade of bone mineralization, high rate of fractures, increased rate of osteoporosis, and intense bone associated pain (Godt *et al.* 2006). Lead can cause impaired mental development, neurotoxicity and anemia (Flora 2002). To this end, the authors thus suggest that roadside gardens in cities with high traffic densities be discouraged because of the health implication of consuming plants with high levels of heavy metals.

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