# Heavy metal contamination of some leafy vegetables growing within Ibadan metropolis, South-western Nigeria.

Sola Ogunyemi*, O.O. Bamgbose and R.O. Awodoyin
Department of Crop Protection and Environmental Biology, University of Ibadan, Ibadan.
E-mail : solaogunyemi2003@yahoo.com; frawodoyin@yahoo.com

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## ABSTRACT

**Most vegetable farms in urban areas of Nigeria are located by the roadside, where environment is heavily polluted with heavymetal-laden exhaust. Within Ibadan metropolis, *Amaranthus cruentus*, *Celosia argentea* and *Corchorus olitorius* are commonly grown all the year round. Accumulation of lead (Pb) and cadmium (Cd) in the three leafy vegetable samples in three different traffic density areas was investigated using atomic absorption spectrophotometric technique. Results revealed that the highest concentrations of Pb and Cd in vegetables were present in samples taken from the high traffic density area. Lead and cadmium concentrations varied among vegetable types. The unwashed leaves of *Amaranthus* had the highest lead (157.69±21.52µg/g) and cadmium (138.76±26.92µg/g) concentrations. The amount of heavy metal removed by washing the plant materials in distilled water was in the range of 6.93 to 53.27% (mean=28.37%) for lead and 19.82 to 72.64% (mean=44.64%) for cadmium. This may imply that in terms of deposition on the plants there was more of cadmium than lead and in term of assimilation into the tissues there was more of lead than cadmium. The implication of continuous ingestion of these contaminated vegetables for bioaccumulation and bio-magnification of the heavy metals in the digestive system of vegetable consumers is discussed.**

*Keywords:* Air pollution, bioaccumulation, cadmium, lead, potherbs, traffic

## INTRODUCTION

Over the years, many human diseases have been traced to pollution of the environment. Pollution is defined as the alteration or modification of the environment by the introduction of solid, liquid or gaseous substances at concentrations injurious to man, plants and animals (Chaudry *et al.* 1989).

The combustion of fossil fuel and motor traffic exhaust is known to constitute a major source of pollution, particularly in the third world countries where leaded fuel is still being used. Nriagu (1989) reported that emission of Pb from gasoline combustion appears to be the world's most important and widespread heavy-metal emission. It has also been established that elevated levels of Cd and Pb in plants are closely associated with proximity to automobile traffic (Largerwerff and Specht 1970). Onianwa and Ajayi (1987) reported that urban activities such as large-scale refuse burning, welding and small metal works account for high levels of cadmium in highly populated urban centre. Thus, Pb and Cd are the heavy metals of great concern, as their presence in the food chain is known to have serious health implications.

*Corresponding author

Several publications have reviewed contamination of roadsides with Pb and Cd and the uptake of these heavy metals by plants (Lee 1972, Ndiowkemere 1984, Onianwa and Ajayi 1987, Alloyway and Jackson 1991). Yet, in recent years, particularly in urban areas close to cities, there has been a dramatic increase in vegetable gardening. In the urban and peri-urban areas, most of these vegetable farms are located by the roadside where there is easy access to water supply, fertilizer, other farm input and, most especially, ready market for produce (UNDP 1996). The safety of these vegetables from urban gardens/farm in term of heavy metal contamination is, therefore, of concern.

However, there is little information on the level of these heavy metals in vegetables grown in urban and peri-urban gardens in Nigeria. The thrust of this study was to determine the extent of Pb and Cd contamination in three common leafy vegetables grown in close proximity to the roads with varying traffic density in Ibadan metropolis, and to assess their concentrations with the distance from the road.

## MATERIALS AND METHODS

On the basis of traffic density, three vegetable producing farms were selected within Ibadan

Metropolis in Southwestern Nigeria. The farms were located at:

(i) Dairy farm Iwo Road (High traffic density area, HTD) with 21,888 vehicles/day.
(ii) Eleyele Water Works Area (Medium traffic density area, MTD) with 14,962 vehicles/day.
(iii) Practical Year Training Farm, University of Ibadan (Low traffic density area, LTD) with 8,582 vehicles/day.

The Iwo Road Dairy farm vegetable garden was about 30m from the paved way, the Eleyele Water Works farm was about 45m from the paved road and the University of Ibadan vegetable farm was about 10m each from the Faculty of Agriculture/Forestry and Faculty of Education roads. Samples were collected in the dry season when most farmers practised 'Fadama' irrigation planting.

Sampling points were systematically located at 10 m, 20 m and 30 m distances from the edge of the road along transects laid across the farm. Samples (3 kg each) of *Amaranthus cruentus, Celosia argentea* and *Corchorus olitorius* were randomly collected at each sampling point. Each sample was divided into two sub-samples. One was thoroughly washed in distilled water while the other was unwashed. All samples were oven dried at 80° C for 48 hours, ground and sieved with a 1mm sieve. Soil samples were also collected from each of the sampling points. All samples were kept in labelled containers prior to digestion. The digestion of plant and soil samples were done following Allen *et al* (1976) and analysed for lead and cadmium using the atomic absorption spectrophotometer (BulkScientific200A Model).

The data collected were subjected to 2-way analysis of variances (SAS 1987) and Duncan's multiple range test for separation of the means at 5% probability level. Percentage difference in the heavy metals between unwashed and washed samples were calculated from the formula:

[(Unwashed - washed)/unwashed] X 100 %

## RESULTS

### pH, Pb and Cd concentrations of soils

The soils from different sampling sites contained different concentrations of Pb and Cd. These soils were also generally acidic with pH ranging from 4.6-6.6. The soil from high traffic density (HTD) area had a mean pH of 5.4, while that of the moderate traffic density (MTD) and low traffic density (LTD) areas had mean pH of 5.7 and 5.9, respectively (Table 1).

There were significant differences in the distribution of lead at each site. The same trend was observed for cadmium except for MTD area where Cd was relatively evenly distributed within the site (Table 1).

### Lead and Cadmium Contents in the Vegetables

All vegetables samples contained different concentrations of Pb and Cd. In unwashed samples the highest lead (157.69 μg/g) concentration was recorded in *A. cruentus* at the HTD area, whereas in washed samples the highest concentration (117.10 μg/g) was still recorded in *A. cruentus* but at the MTD area (Table 2). The highest cadmium in unwashed samples (138.76 μg/g) was recorded in *A. cruentus* at MTD area, but in washed samples the highest concentration (42.58 μg/g) was recorded in *C. olitorius* at the HTD area (Table 3).

The amount of these heavy-metals in each vegetable varied among sampling sites in the three traffic density areas, though specific trends could not be identified. In unwashed samples concentration of Pb and Cd followed the order HTD>MTD>LTD except in *A. cruentus* where the trend of Pb concentration was HTD>LTD>MTD (Tables 2 and 3). In washed samples of the three vegetable types, the concentrations of two heavy-metals did not follow a specific trend.

At the HTD area, sampling points were significantly ($P<0.05$) different with regards to the

**Table 1: Soil pH, Pb and Cd concentration at various distances from farm edge in three traffic density areas. (Values are means of three replicates).**

| Distance(m) | High traffic density | | | Moderate traffic density | | | Low traffic density | | |
|---|---|---|---|---|---|---|---|---|---|
| | pH | Cd (μg/g) | Pb (μg/g) | pH | Cd (μg/g) | Pb (μg/g) | pH | Cd (μg/g) | Pb (μg/g) |
| 10 | 5.6 | 31.94$^{a}$ | 24.18$^{a}$ | 6.6 | 5.46$^{a}$ | 26.66$^{b}$ | 5.5 | 19.40$^{a}$ | 9.12$^{c}$ |
| 20 | 4.9 | 11.67$^{b}$ | 21.11$^{c}$ | 5.9 | 5.61$^{a}$ | 26.73$^{a}$ | 6.5 | 14.95$^{c}$ | 39.32$^{a}$ |
| 30 | 5.6 | 3.27$^{c}$ | 22.78$^{b}$ | 4.6 | 4.81$^{a}$ | 24.73$^{c}$ | 5.7 | 25.91$^{a}$ | 27.45$^{b}$ |
| Mean | 5.4 | - | - | 5.7 | - | - | 5.9 | - | - |

Means in a column with the same letter are not significantly different at 5% level of probability using Duncan's multiple range test.

**Table 2. Pooled mean of lead (µg/g) contents in unwashed and washed samples of *Celosia argentea*, *Amaranthus cruentus* and *Corchorus olitorius* in three traffic density areas in Ibadan metropolis. (Values are means ± S.E; n=3).**

| Plant species | Traffic densities | | |
|---|---|---|---|
| | High | Moderate | Low |
| | **Unwashed** | | |
| *Celosia argentea* | 134.50±5.48 | 102.18±5.00 | 89.87±10.62 |
| *Amaranthus cruentus* | 157.70±21.52 | 130.75±11.43 | 133.09±10.72 |
| *Corchorus olitorius* | 115.60±2.55 | 99.19±14.58 | 86.76±4.80 |
| | **Washed** | | |
| *Celosia argentea* | 62.85±10.40 | 86.19±7.29 | 83.64±11.35 |
| *Amaranthus cruentus* | 74.03±20.74 | 117.10±11.97 | 87.22±6.50 |
| *Corchorus olitorius* | 86.67±10.05 | 70.55±11.09 | 62.33±18.40 |

**Table 3. Pooled mean of cadmium (µg/g) contents in unwashed and washed samples of *Celosia argentea*, *Amaranthus cruentus* and *Corchorus olitorius* in three traffic density areas in Ibadan metropolis. (Values are means ± S.E; n=3).**

| Plant species | Traffic densities | | |
|---|---|---|---|
| | High | Moderate | Low |
| | **Unwashed** | | |
| *Celosia argentea* | 85.91±45.43 | 47.13±5.09 | 28.96±5.00 |
| *Amaranthus cruentus* | 138.76±26.92 | 63.32±21.04 | 47.86±1.40 |
| *Corchorus olitorius* | 68.15±17.51 | 48.84±18.06 | 29.22±5.63 |
| | **Washed** | | |
| *Celosia argentea* | 38.58±1.03 | 25.84±2.59 | 18.69±2.17 |
| *Amaranthus cruentus* | 37.97±3.26 | 33.52±5.04 | 34.40±1.00 |
| *Corchorus olitorius* | 42.58±6.00 | 19.09±5.05 | 23.43±1.38 |

amount of Pb in the vegetable. However, for *Amaranthus cruentus* at the MTD area, samples taken at 10 m and 20 m distances from the edge of the farm did not differ significantly in their Pb contents. Also, the Pb concentration in *Corchorus olitorius* taken at 10 m and 30 m distances from the edge of the farm did not differ significantly at HTD, while samples taken at 10 m and 20 m distances from the edge of the farm at the LTD were not significantly different (Table 4).

The vegetables contained different concentrations of cadmium. However, the occurrence of Cd in *Celosia argentea* and *Corchorus olitorius* at 10 m and 20 m distances from the farm edges at the LTD area, and in *C. argentea* at 20 m and 30 m distances from edge at the MTD area did not differ significantly (Table 5).

Washing the vegetable samples reduced the concentrations of both Pb and Cd in the vegetables at the three traffic density areas. The amount of lead removed by washing ranged between 6.93% in *C. argentea* at the LTD area to 53.27% in the same *C. argentea* at the HTD area, whereas the amount of cadmium removed by washing ranged from 19.82% in *C. olitorius* at the LTD area to 72.64% in *A. cruentus* at the HTD area (Table 6). On average, washing removed about 28.37% of Pb and 44.64% of cadmium from the vegetables. The concentrations of heavy metals removed from *C. olitorius* by washing were 25.03% and 37.52% for

**Table 4. Lead (µg/g) contents in unwashed and washed samples of *Celosia argentea*, *Amaranthus cruentus* and *Corchorus olitorius* at varying distances from the roadside in three traffic density areas in Ibadan metropolis.**

| Distance from farm edge (m) | *Celosia argentea* | | *Amaranthus cruentus* | | *Corchorus olitorius* | |
|---|---|---|---|---|---|---|
| | Washed | Unwashed | Washed | Unwashed | Washed | Unwashed |
| | | | **High traffic density** | | | |
| 10 | 126.8[c] | 54.46[c] | 166.71[b] | 52.10[b] | 112.18[b] | 98.59[a] |
| 20 | 145.1[a] | 50.56[b] | 189.63[a] | 54.51[b] | 120.62[a] | 94.76[a] |
| 30 | 131.6[b] | 83.54[a] | 116.75[c] | 115.49[a] | 113.89[b] | 66.69[b] |
| | | | **Moderate traffic density** | | | |
| 10 | 107.36[a] | 83.01[b] | 153.05[a] | 139.97[a] | 127.63[a] | 92.05[a] |
| 20 | 107.00[a] | 100.11[a] | 123.93[b] | 11.81[b] | 90.51[b] | 55.05[c] |
| 30 | 92.19[b] | 75.46[c] | 115.27[c] | 99.53[c] | 79.43[c] | 64.56[b] |
| | | | **Low traffic density** | | | |
| 10 | 106.12[a] | 100.93[a] | 146.07[a] | 77.22[c] | 92.82[a] | 91.72[a] |
| 20 | 69.90[c] | 62.27[c] | 141.37[b] | 85.03[b] | 90.17[a] | 66.82[b] |
| 30 | 93.60[b] | 87.73[b] | 11.83[c] | 99.41[a] | 77.29[b] | 28.45[c] |

Means in a column of each vegetable type in each traffic density area with the same letter are not significantly different at 5% level of probability using Duncan's multiple range test.

**Table 5. Cadmium (µg/g) contents in unwashed and washed samples of *Celosia argentea*, *Amaranthus cruentus* and *Corchorus olitorius* at varying distances from the roadside in three traffic density areas in Ibadan metropolis.**

| Distance from farm edge (m) | *Celosia argentea* | | *Amaranthus cruentus* | | *Corchorus olitorius* | |
|---|---|---|---|---|---|---|
| | Washed | Unwashed | Washed | Unwashed | Washed | Unwashed |
| | | | **High traffic density** | | | |
| 10 | 43.79$^{b}$ | 40.57$^{a}$ | 88.11$^{c}$ | 43.58$^{a}$ | 52.42$^{b}$ | 46.19$^{a}$ |
| 20 | 37.23$^{c}$ | 37.10$^{b}$ | 148.27$^{b}$ | 38.03$^{b}$ | 103.11$^{a}$ | 50.69$^{b}$ |
| 30 | 176.71$^{a}$ | 38.07$^{b}$ | 179.91$^{a}$ | 32.29$^{b}$ | 48.92$^{c}$ | 30.86$^{c}$ |
| | | | **Moderate traffic density** | | | |
| 10 | 37.06$^{a}$ | 22.09$^{c}$ | 48.67$^{b}$ | 41.14$^{a}$ | 29.77$^{c}$ | 12.74$^{c}$ |
| 20 | 53.50$^{a}$ | 24.63$^{b}$ | 36.49$^{c}$ | 35.42$^{b}$ | 84.95$^{a}$ | 15.52$^{b}$ |
| 30 | 50.84$^{a}$ | 30.811$^{a}$ | 104.81$^{a}$ | 24.01$^{c}$ | 31.81$^{b}$ | 29.06$^{a}$ |
| | | | **Low traffic density** | | | |
| 10 | 24.23$^{b}$ | 16.34$^{b}$ | 48.64$^{a}$ | 35.88$^{a}$ | 23.79$^{b}$ | 20.80$^{c}$ |
| 20 | 23.77$^{b}$ | 16.34$^{b}$ | 48.64$^{a}$ | 35.88$^{a}$ | 23.79$^{b}$ | 20.80$^{c}$ |
| 30 | 38.87$^{a}$ | 16.71$^{b}$ | 49.80$^{a}$ | 32.50$^{a}$ | 40.49$^{a}$ | 25.47$^{a}$ |

Means in a column of each vegetable type in each traffic density area with the same letter are not significantly different at 5% level of probability using Duncan's multiple range test.

Pb and Cd respectively. However, in *A. cruentus* the concentrations were 53.05% of Pb and 72.64% of Cd, and in *C. argentea* the concentrations were 53.27% of Pb and 55.09% of Cd (Table 6).

**Table 6. Percentage reduction of lead and cadmium by washing the samples of *Celosia argentea*, *Amaranthus cruentus* and *Corchorus olitorius* in distilled water.**

| Plant species | Traffic densities | | | |
|---|---|---|---|---|
| | High | Moderate | Low | Mean |
| | | **Lead** | | |
| *Celosia argentea* | 53.27 | 15.65 | 6.93 | 25.28 |
| *Amaranthus cruentus* | 53.05 | 10.44 | 34.47 | 32.65 |
| *Corchorus olitorius* | 25.03 | 28.87 | 27.66 | 27.19 |
| | | **Cadmium** | | |
| *Celosia argentea* | 55.09 | 45.17 | 35.46 | 45.24 |
| *Amaranthus cruentus* | 72.64 | 47.06 | 28.12 | 49.27 |
| *Corchorus olitorius* | 37.52 | 60.91 | 19.82 | 39.41 |

## DISCUSSION AND CONCLUSION

The results showed that heavy metal concentration in the unwashed vegetable species, which accounted for the amount of surface deposition and assimilation of heavy metals depend on vehicular traffic density. The overall lead and cadmium concentration were also highest in areas with high traffic density (HTD). Onianwa (1987) working with acrocarpous mosses to monitor pollution in the air reported that mosses collected within villages with low population and low traffic density had low Pb (14.3±7.0µg/g) and low cadmium (0.12±0.15µg/g) concentrations compared to high concentrations (136±77µg/g for Pb; 0.35±0.21µg/g for Cd) obtained in Ibadan with high population, high traffic density and high anthropogenic activities such as large scale refuse burning, welding and small metal works. Lee (1972) reported that in Manchester, England, Pb levels of 185 µg/g in most parts of the city increased to 320 µg/g at 2m from roadsides. The phenomenal increase in automobile traffic in recent times within Ibadan City has been reported to be a major source of various atmospheric pollution (Oluwande 1977, Osibanjo and Ajayi 1980).

The low concentration of heavy metals in washed samples at the LTD implies that heavy metal deposition was low. Nasralla and Alli (1985) reported that heavy metal concentration of fruits was the result of traffic densities and distances of the farms or gardens from roadsides. They further reported that the primary source of Pb in leaves growing close to public roads was from leaf absorption of tetra-ethyl lead vapor and salts emitted from motor vehicles.

The low concentrations of heavy metals in the soil when compared to the plant would indicate that the availability of soil Cd and Pb to the plant was negligible. It could, therefore, be inferred that the source of Cd and Pb to the vegetables was from aerial deposition and foliar absorption. Various authors have reported that retention of particulate matter is the main source of contamination of roadside vegetation (Little 1973, Chamberlin 1997).

In unwashed samples the differences in heavy metal concentrations across various distances from edge of the road , though did not follow a specific trend, may reflect difference in the aerial deposition as aided by wind drift. Wind drift action may have aided the deposition of Pb since wind velocity affects and sometimes may increase deposition of atmospheric pollutants (Lewinska 1984). Fytiamos *et al* (1985) identified meteorology as one of the factors that affect the concentration of Pb to be found in the various environmental compartments bordering a roadway. The high concentrations of Pb in 20m and 30m distances from edge of the road may imply that fine grained Pb were airborne to a further distance before deposition. Hana and Al-Basam (1983) reported that 25% of the vehicular emitted Pb is coarse grained and deposited close to the road, while the remaining 75% is finer and may be airborne over a long distance.

In HTD area, heavy metal deposition on *C. olitorus* was far less than deposition on *A. cruentus* and *C. argentea* as indicated by the low percentage of heavy metal removed by washing. *A. cruentus* indicatively had highest surface deposition. The variation in concentrations of Pb and Cd among vegetable types (unwashed) may be explained by differences in leaf morphology. Leaf morphology has been implicated in the relative ability of plant species to absorb and retain heavy metals. The *Amaranthus* sp. used in this investigation had broader leaves than the other two vegetables. Also *C. olitorius* had shiny glabrous leaf surface that may not aid retention. Gradual retention and accumulation of surface Pb and other heavy metals have been demonstrated to be dependent on leaf shape and size, and on the general morphology of plants (Martin and Coughtrey 1981, Kingston *et al* 1988).

Washing removed a considerable amount of heavy metals, as high as 72.64% of Cd in *A. cruentus* at the HTD area. It has been reported that up to 80% of the total Pb content in leaves could be removed by rinsing with distilled water (Schodeller 1967, Breckle and Verche 1974). Also, reports of Hagemeyer *et al* (1986) and Lindeberg and Harris (1994) demonstrated the efficiency of washing in reducing the amount of Cd in plant leaves. This may further imply that the main source of Pb and Cd pollution in vegetables is aerial deposition from motor vehicle emissions and other athropogenic activities.

Washing the vegetables in distilled water removed relatively more Cd than Pb, but the concentrations of these pollutants in the washed vegetables were still above internationally acceptable levels. Kloke (1974) recommended that maximum food content of Pb should be 10μg/g. However, FAO/WHO (1978) recommended maximum tolerable daily Pb intake of 0.00043 μg/g or 7 μg/kg-body weight. Few of the vegetables samples had Cd level higher than the recommended tolerable level. WHO/UNEP (1976) recommended daily intake of 57.14-71.43 μg/kg-body weight.

The relatively high concentrations of Pb and Cd in these common leafy vegetables raise some serious environmental concerns. Both lead and cadmium have been shown to be toxic to man. Cadmium, inhaled or ingested, is known to be a cumulative poison in man. The liver and kidney are known to contain half the total cadmium in the body and its bioaccumulation in the system has been related to hypertension and cardiovascular diseases (Underwood 1971). Acute effects of Pb poisoning could lead to constipation, vomiting, anaemia, swelling of the brain, paralysis and even death (Shapiro and Johnson 1989). Lead is also known to interfere with the function of the mitochondria, thereby impairing respiration (Chang 1992)

Continuous consumption of heavy metal-contaminated vegetables could have serious health implication in the developing countries where leaded fuel is very much in use. Now that cities in Nigeria are crammed with poorly maintained heavy metal-emitting vehicles, environmentalist have the responsibility of monitoring the level of pollutants being ingested by city dwellers. It is recommended that steps be taken to discourage the cultivation of leafy vegetables along roadside and especially, in high traffic density (HTD) areas.

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