

Bioaccumulation of Heavy Metals by *Moringa Oleifera* in Automobile Workshops from three Selected Local Governments Area, Ibadan, Nigeria

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Abstract

Plants accumulate minerals essential for their growth from the environment alongside with heavy metals from contaminated areas. This study investigated bioaccumulation of heavy metals by *Moringa oleifera* in automobile workshops in three selected local government areas in Ibadan. This was done with a view to determining the concentration and type of heavy metals accumulated in the tissues of *Moringa oleifera* grown around automobile workshops. Barks, leaves and seeds of *M. oleifera* were collected from three automobile workshops in each of the local government area and from a control site. The samples were dried, ground and analyzed for heavy metals content (Cu, As, Pb, Cd, Cr, Mn and Zn) using ICP-MS. The mean level of heavy metals obtained ranged from 0.018 ± 0.001 to 0.356 ± 0.021 in the leaves, 0.012 ± 0.001 to 0.255 ± 0.016 in the seed and 0.048 ± 0.003 to 0.989 ± 0.003 in the bark. The concentration of heavy metals recorded followed the trend of $\text{Cu} > \text{Zn} > \text{Mn} > \text{Pb} > \text{Cr} > \text{As}$ in the leaves; $\text{Zn} > \text{Cu} > \text{Pb} > \text{Cr} = \text{Mn} > \text{As}$ in the seeds and $\text{Zn} > \text{Cu} > \text{Mn} > \text{Pb} > \text{Cr} > \text{As}$ in the barks. The overall concentration of heavy metals bioaccumulated by this plant follows the trend; bark > leaves > seeds. The increase in the concentrations of heavy metals observed in the barks, leaves and seeds of *M. oleifera* collected from automobile workshops to that of control site indicated the impact of mechanical activities in introducing trace metals to the environment. The study further suggested that *Moringa olifera* in polluted sites may accumulate trace metals in any of its parts; hence care should be taken when harvesting the plant for medicinal purpose.

Introduction

In recent years, significant attention has been paid to the problem of environmental contamination by a wide variety of chemical pollutants including heavy metals (Isola *et al.*, 2015). These chemicals arise from increasing levels of anthropogenic activities such as industrialization and urbanization, coal and metals ore mining, chemical manufacturing, petroleum mining and refining, electric power generation, melting

and metal refining, metal plating and to some extent domestic sewage. Little attention has been paid to automobile mechanic activities and workshops as one of the major sources of heavy metals pollution in the environment (Adewole & Uchebun 2010; Abidemi 2011; Okoro *et al.* 2013). Odiwe *et al.* (2014) has also worked on heavy metals pollution in automobile workshops.

In Nigeria, numbers of automobile workshops have increased mainly due to large

in flow of used vehicles popularly known as “Tokunbo” into the country. These automobile workshops are usually not registered but assist low income earners patronizing the workshop for repairs and maintenance activities and as such contributed remarkably to the problem of soil contamination in most cities in the country (EEA, 2007). Most of these road side automobile workshops dispose their waste oil and fossil fuel among others into their nearby soil, stream or river thereby polluting the environment. The indiscriminate disposal of these waste engine oil into gutters, water drains, open vacant plots, and farm land is a common practice in Nigeria, and this has led to a significant environmental pollution (Akinpelumi & Olatunji, 2015). These wastes engine oil contain heavy metals such as Cd, Cr, Pb, and Fe, Ni, Zn, Co, Cu, Ba (Elena *et al.*, 2004; Ilemobayo & Kolade 2008). When the environment is contaminated with these heavy metals, organisms tend to absorb these toxic substances (heavy metals or chemicals) at a rate faster than that at which the substance is lost. (Bryan & Waldichuk, 2012).

Plants accumulate minerals essential for their growth from the environment and may accumulate some metals which have no known direct benefit to the plants (Ademoroti, 1986). However, the rate at which various species of wild plants growing in the same habitats accumulate heavy metals may vary considerably (Bylińska, 1995). Detailed ecological studies enabled the distinction of species with particular accumulative capacities with respect to one or several heavy metals, thereby serving as bioindicators of contaminated areas (Holoubek *et al.*, 2000). Research findings

by Divrikli *et al.* (2006) have shown that the concentration of essential elements in plants is conditional; as it is affected by the characteristics of the soil and the ability of plants to selectively accumulate some of these metals.

Over the years, man has relied so much on medicinal plants for health and food needs (Nwachukwu *et al.*, 2010). The traditional uses of medicinal plants for curing and preventing illnesses, including the promotion of both physical and spiritual well-being of humans are well documented (Idu & Onyibe, 2007). The use of medicinal herbs to relieve and treat many human diseases is increasing around the world due to their mild features and low side effects (Yap *et al.*, 2010). World Health Organization (WHO, 2007) survey indicated that about 70–80% of the world population relies on non-conventional medicine, mainly of herbal sources, in their primary health care. This report revealed that medicinal plants and their trace elements play an important role in the treatment of diseases (Chan, 2003).

Heavy metals are known to bioaccumulate and thus disrupt functions of vital organs and glands in the human body, affecting brain, kidney and liver (Suranjana & Manas, 2009). Medicinal plants can be contaminated by these heavy metals via root uptake or by direct deposition of contaminants from the atmosphere onto plant surfaces (Dzomba *et al.*, 2012; Olowoyo *et al.*, 2011). It is recommended that herbal drugs should not be used without qualitative and quantitative analysis of their heavy metal contents. In an attempt to control pollution of medical plants by heavy metal (WHO, 2005), World Health Organisation regulated maximum

permissible limits of heavy metals like arsenic, cadmium and lead to 0.1, 0.3, 5.0 mg/kg, respectively (WHO, 1998; 2007). Ingestion of high concentration of heavy metals such as chromium, cadmium and lead can affect growth rate, cause hepatic and renal impairment (Blowes, 2002).

Moringa oleifera (drumstick tree), popularly known in many countries as a “miracle plant” because of its nutritional and medical properties has a great bio-energy potential and is an exceptionally nutritious vegetable tree with many uses (Ozumba 2008; Onyekwelu & Olabiwonnu, 2010). *Moringa* is rich in many vitamins, including vitamin A, several forms of vitamins B, C, D and E. In fact, it has more of these vitamins than many variety of foods (such as carrots, oranges and milk) and is known to be excellent source of these vitamins (Zarkada *et al.*, 1997). Moringa leaves are edible and they form part of traditional diets in many countries (Odee, 1998). The leaves are rich in protein, vitamins and minerals (Fuglie, 2006). Despite the aforementioned benefit of *Moringa oleifera*, little is known about its bioaccumulation potentials in the face of ever increasing environmental contamination. This study therefore assesses the level of heavy metals and the different types of heavy metals accumulated in *M. oleifera* growing around automobile workshops.

Materials and method

Sample collection and preparation

Three automobile workshops were chosen each from Ibadan North East (N7.440336, E3.911842; N7.441624, E3.914147; N7.424374, E3.899876), Lagelu (N7.443190, E3.951608; N7.449785, E3.950738; N7.488312, E3.985640) and

Akinyele Local Government (N7.458252, E3.918772; N7.458699, E3.918278; N7.455890, E3.920081) in Oyo state due to heavy automobile operations and presence of *M. oleifera* in this area.

Six Moringa trees were carefully selected for fresh leaves, barks and seeds in each of the chosen automobile workshops. Healthy trees with diameter of 30 cm and 20 m away from each other but within the chosen automobile workshop were sampled. In order to have a basis for scientific comparison, Fresh leaves, barks and seeds of *M. oleifera* were also collected from Botanical garden, Polytechnic Ibadan and used as control for this experiment. The average age of the *M. oleifera* used for this study was five (5) years. The full barks were carefully removed from the tree trunk at an average height of 1.5 m with stainless steel knife. Prior to collection, debris at the bark of the tree were carefully removed with synthetic hard brush. The plant samples were rinsed and oven dried at 80 °C until a constant weight. The oven-dried samples were abridged into small pieces using laboratory mill.

Chemical analysis

The various plant sample parts collected were oven-dried at 80 °C until a constant weight was reached and ground for chemical analyses. The ground plant samples were digested using the mixed acid (nitric-perchloric-sulphuric) digestion procedure of Allen *et al.* (1974). 0.2 g each of ground sample was digested in 7.0 mL of the digestion mixture. The digested samples were analyzed for Cu, Zn, Pb, Mn, and Cr in order to determine the level of heavy metals accumulation, using an ICP-MS

(High Resolution ICP-MS Model:Agilent 7500).

Statistical analysis

The means of heavy metals were compared across the sites in each of the plant parts (bark, leaves and seeds) using one way Analysis of Variance (ANOVA) and means of heavy metals concentration in different parts of the plant were separated using Duncan Multiple Range Test.

Results

Heavy metals concentration in tree bark samples from the three sampling sites along with the control samples are presented in Table 1. The results indicated that tree bark samples from Ibadan North East had higher concentrations of most of the elements than those samples from the other two sites (Akinyele and Lagelu local government) and the control. The concentration of Cu, As, Pb, Cr, Mn and Zn in Ibadan North East were significantly higher ($P < 0.05$) compared to the other plots. However, there is no significant difference in Cu, As, Pb, and Mn concentrations in the sample collected from Akinyele and Lagelu local government but they differ significantly from those of the control ($P < 0.05$).

Chromium (Cr) and Zinc (Zn) concentrations in the bark of *M. oleifera* was not only significantly higher in Ibadan North East (0.099 mg/kg and 0.989 mg/kg) but also significantly different Akinyele and Lagelu local government (0.054 mg/kg, 0.622 mg/kg and 0.074 mg/kg, 0.744 mg/kg), respectively.

The mean concentrations of Cr, Cu, Mn, Pb and Zn in seed samples from the three chosen sites and the control are summarized in Table 2. The results showed higher significant levels ($P < 0.05$) of metal concentrations in seed samples obtained from Ibadan North East compared with those obtained from Akinyele, Lagelu and the control. Pb was not detected in the seed collected from the control, other available metals were significantly ($P < 0.05$) lower when compared to the other chosen sites. There was no significant difference in the concentration of Pb in seeds from Akinyele and Ibadan North East. However, they both differ from those of Lagelu local government. The highest mean concentrations of Mn and Zn were recorded for seeds of *M. oleifera* collected from mechanic workshop in Ibadan North East each with concentration of 0.022 and 0.300 mg/kg respectively, while the control had the

TABLE 1
Concentration of heavy metals present in the bark of *M. oleifera* collected from three different local governments in Ibadan

Locations	Cu (mg/kg)	As (mg/kg)	Pb (mg/kg)	Cr (mg/kg)	Mn (mg/kg)	Zn (mg/kg)
(n = 6)						
Akinyele	0.700±0.029 ^b	0.048±0.003 ^b	0.065±0.004 ^b	0.054±0.003 ^c	0.065±0.002 ^b	0.622±0.033 ^c
Lagelu	0.700±0.029 ^b	0.053±0.003 ^b	0.076±0.004 ^b	0.074±0.003 ^b	0.067±0.002 ^b	0.744±0.033 ^b
Ibadan North East	0.845±0.029 ^a	0.075±0.003 ^a	0.099±0.004 ^a	0.099±0.003 ^a	0.117±0.002 ^a	0.989±0.033 ^a
Control	0.367±0.029 ^c	0.027±0.003 ^c	0.030±0.004 ^c	0.023±0.003 ^d	0.033±0.002 ^c	0.400±0.033 ^d

*Means with different alphabet in a column are significantly different ($P < 0.05$).

TABLE 2
Concentration of Heavy metals in seeds of *M. oleifera*

Locations	Cu (mg/kg)	Pb (mg/kg)	Cr (mg/kg)	Mn (mg/kg)	Zn (mg/kg)
(n=6)					
Akinyele Lagelu	0.233±0.016 ^a	0.027±0.001 ^a	0.018±0.001 ^a	0.016±0.002 ^{ab}	0.234±0.021 ^{ab}
Ibadan North East					
Control	0.178±0.016 ^b	0.018±0.001 ^b	0.012±0.001 ^b	0.014±0.002 ^b	0.200±0.021 ^b
(Botanical garden)	0.255±0.016 ^a	0.029±0.001 ^a	0.022±0.001 ^a	0.022±0.002 ^a	0.300±0.021 ^a
	0.100±0.016 ^c	ND	0.010±0.001 ^b	0.007±0.002 ^c	0.100±0.021 ^c

*Means with different alphabet in a column are significantly different ($P < 0.05$)

ND = Not detected

least concentration of 0.007 and 0.100 mg/kg of Mn and Zn respectively. Lastly, among all the heavy metals detected, Zn was observed to have the highest mean concentration of 0.300 mg/kg in the seeds. In all the locations, As was not detected in the seeds of *M. oleifera*.

For the heavy metal concentration in the leave of the *M. oleifera* studied, the concentration of Cu was significantly different in all the studied plots. *M. oleifera* collected from mechanic workshops in Ibadan North East had the highest concentration of Cu (0.433 mg/kg) which is significantly different from all other local governments and control. The control had the least concentration of Cu (0.167 mg/kg). The leaves of *M. oleifera* from mechanic workshops in Ibadan North East had the highest As, Pb and Cr mean value which is significantly different from those of Akinyele and Lagelu. The control had the least concentration of Pb while both As and Cr were not detected. There is no significant difference in Mn concentration for the entire site including the control. However, leaves

collected from mechanic workshops in Ibadan North East had the highest mean concentration of 0.060 mg/kg while the control had the lowest mean concentration of 0.013 mg/kg. The mean concentration of Zn recorded in leaves collected from Ibadan North East had the highest mean value of 0.278 mg/kg while the control had the least (0.133 mg/kg). Among all the heavy metals detected, Cu was observed to have the highest mean concentration (0.433 mg/kg) while As and Cr in the controls site were below detectable level (Table 3).

Comparing the concentration of heavy metals detected in the various parts of *M. oleifera* collected from the three local governments and the control, the heavy metals such as Cu, As, Pb, Cr, Mn and Zn had the highest concentrations in the barks of *M. oleifera* and the least in the seeds with As being below detectable level in the seed. Unlike other heavy metals, Zn was the only heavy metal that had the highest concentration in all the parts of *M. oleifera* followed closely by Cu (Table 4). Generally, the concentration of heavy metals in the different part of *M. oleifera* sampled followed the order of $Cu > Zn > Mn > Pb >$

TABLE 3
Heavy metals concentrations in leaves of *M. oleifera*

Locations	Cu (mg/kg)	As (mg/kg)	Pb (mg/kg)	Cr (mg/kg)	Mn (mg/kg)	Zn (mg/kg)
<i>(n = 6)</i>						
Akinyele	0.356 ± 0.021 ^b	0.014 ± 0.002 ^b	0.023 ± 0.002 ^b	0.020 ± 0.001 ^b	0.023 ± 0.016 ^a	0.233 ± 0.021 ^{ab}
Lagelu	0.278 ± 0.021 ^c	0.016 ± 0.002 ^b	0.021 ± 0.002 ^b	0.018 ± 0.001 ^b	0.018 ± 0.016 ^a	0.178 ± 0.021 ^{bc}
Ibadan	0.433 ± 0.021 ^a	0.024 ± 0.002 ^a	0.034 ± 0.002 ^a	0.030 ± 0.001 ^a	0.060 ± 0.016 ^a	0.278 ± 0.021 ^a
North East						
Control	0.167 ± 0.021 ^d	ND	0.013 ± 0.002 ^c	ND	0.013 ± 0.016 ^a	0.133 ± 0.021 ^c

Means with different alphabet in the column are significantly different ($P < 0.05$)

ND = Not detected

TABLE 4
Comparison of heavy metals detected among different parts of *M. oleifera* collected from three local governments in Ibadan

Plant Parts	Cu (mg/kg)	As (mg/kg)	Pb (mg/kg)	Cr (mg/kg)	Mn (mg/kg)	Zn (mg/kg)
Leaves	0.356 ± 0.040 ^b	0.018 ± 0.005 ^b	0.026 ± 0.007 ^b	0.023 ± 0.008 ^b	0.034 ± 0.013 ^b	0.230 ± 0.067 ^b
Seeds	0.222 ± 0.040 ^b	ND	0.025 ± 0.007 ^b	0.017 ± 0.008 ^b	0.017 ± 0.013 ^b	0.245 ± 0.067 ^b
Bark	0.748 ± 0.040 ^a	0.059 ± 0.005 ^a	0.080 ± 0.007 ^a	0.076 ± 0.008 ^a	0.083 ± 0.013 ^a	0.785 ± 0.067 ^a

*Means with different alphabet in the column are significantly different ($P < 0.05$)

ND = Not detected

Cr > As followed by Zn > Cu > Pb > Cr > Mn > As in seeds and Zn > Cu > Mn > Pb > Cr > As in the bark. The overall concentration of heavy metals in the plant follows this trend of bark > leaves > seeds.

Discussion

The levels of heavy metals found in the bark, leaves and seeds of *M. oleifera* sampled indicated appreciable build up of different heavy metals in this plant growing around the vicinity of mechanic workshops and this agrees with earlier findings of Vwioko *et al.* (2006) and Agbogidi (2009) that plants in polluted soil and environment have the tendency of accumulating toxic contents of the polluted environment in their tissues. The observed increase in the levels

of heavy metals in the various parts of *M. oleifera* collected from mechanic workshops suggested that the activities taken place in the mechanic workshops have a direct impact on the levels of trace metals in the *M. oleifera*, this may also have negative impact on the vegetation growing around the area. Adelekan & Abegunde (2011) have highlighted that different activities (such as discharge of dirty fluid; scrapping or filling of metal bits; discard of waste solder and electrodes after welding and soldering etc.) can introduce heavy metals into the soil in mechanic workshop and subsequently taken up by plants from soil through the roots to various plant parts (foliage and tree bark).

The lower level of some heavy metals such as As and Pb found in the control site

may be attributed to the minimal exposure of the area to pollution. In most cases, Pb and As are known to be a product of vehicular emission or waste emanating from wrong disposal of used batteries (Olowoyo *et al.*, 2013). The same reason can also be attributed to why seeds of *M. oleifera* from the control site had the lowest concentration of heavy metals (Cu, Cr, Mn, Pb and Zn) when compared to those collected from mechanic workshop. This is due to the mechanical activities taken place in that area but absent in the control site. The higher concentration of heavy metals recorded in the leaves, seeds and barks of *M. oleifera* from mechanic workshops might be as a result of higher automobile repair and maintenance activities taken place at the mechanic workshops.

The significant higher levels of heavy metals in the bark of *M. oleifera* collected from mechanic workshops in Ibadan North East local government (i.e. Cu, As, Pb, Cd, Cr, Mn and Zn) compared to other local governments signify the degree of mechanical activities and the frequency of cars being repaired in each of the workshops. The highest heavy metals concentrations observed in the bark of *M. oleifera* collected from Ibadan North East further indicated that the location is more polluted than the other two local governments and may be due to more customers patronizing them than the other two locations.

The significant higher concentration of Cu in the bark of *M. oleifera* collected from automobile mechanic workshops may be attributed to wire and alloys used in automobiles since Cu is the major constituent of wires and alloy. However, the

concentration was still within the tolerance limit of 0.05–15.0 mg/kg given by World Health Organization (WHO, 2007). Pb occurs naturally in soils, the concentration ranges from 1 to 200 mg/kg mean value of 15 mg/kg (Chirenje *et al.*, 2004). The higher value of Pb around the automobile workshop may thus be linked to vehicular emission and re-suspension in the environment since they are not biodegradable. A ready source of the Pb is vehicle batteries which are repaired or otherwise handled in these locations (mechanic workshops) as well as pouring of electrolyte and lead plates on the ground. However, the observed values (0.026 to 0.080) fall within tolerable limit of 0.005–0.1 prescribed by the WHO, 2007.

In the present study, the concentration of heavy metals in the leaves of *M. oleifera* studied followed the order of Cu > Zn > Mn > Pb > Cr > As. This consistent with the same trend reported by Okeke *et al.* (2014) on bioaccumulation of heavy metals in mechanic workshops using *Azadirachta indica*. The concentration of Cr observed in the leaves of *M. oleifera* in the control was within the limit of 0.005–0.01 given by WHO, 2007. It is below detectable level in the seeds but slightly above the WHO limit in the barks collected for the control which explains the fact that the bark of the trees in the polluted sites can bioaccumulate and hence toxic for consumption.

The overall concentration of heavy metals in the plant was observed to assume the trend of bark > leaves > seeds which shows that the bark of the trees can accumulate more heavy metals than all the other plant parts. In this study, the bark of *M. oleifera* from polluted sites had higher metal concentrations than the leaves and seeds in all cases which may be due to the fact that

leaves and seeds spend little period of time on the plant. Older leaves of *M. oleifera* are being shed and continuously being replaced by new ones thereby limiting the accumulation of heavy metals in them. Also the seeds spend little time on the plant before being plucked or shed but the bark remains intact on the plants for longer period than the leaves and seeds. More so, the bark is closer to the source (roots) than the leaves and the seeds which is in accordance with the report of Agbogidi (2009) that heavy metals absorption from soil through roots and subsequent translocation to other parts of plant has higher values at the source (roots) than the sink (other parts) and largely also due to the rough nature of the bark of the tree.

Conclusion

Mechanic workshop is one of the contaminated sites for heavy metals due to the different automobiles repairs and maintenance activities taken place there and plants growing there can easily absorb heavy metals during their metabolism. The concentration of metals in the various part of *M. oleifera* across the three mechanic workshops were statistically higher than that of the control, indicating that the mechanical activities in those areas are greatly impacting its surrounding vegetation and also suggesting that the concentrations of heavy metals in the various part studied can be expected to be an indicator of metal loading. The study demonstrated the ability of *M. oleifera*, especially the bark, as an accumulator of some heavy metals. The levels of trace metals in some parts of *M. oleifera* used suggested that the *M. oleifera* barks can accumulate trace metals in their

tissues; hence, care should be taking when the plant is to be considered for medicinal purpose and the need to regulate where the plants should be cultivated because of its ability to uptake trace metals. Future research should seek to evaluate the ability of this plant to perform effectively as a medicinal plant after accumulating trace metals in any of its part.

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