



Received: 23 October 2015
Accepted: 18 December 2015
First Published: 19 January 2016

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Reviewing editor:
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SOIL & CROP SCIENCES | RESEARCH ARTICLE

Lead and cadmium contents in a medicinal plant/spice grown in an urban city of Nigeria

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Abstract: Human exposure to heavy metals is a growing concern across Nigerian urban settings due to potential danger from consuming plants grown on contaminated soils. This study assessed the contents of lead and cadmium in soil and basil (*Ocimum basilicum* Lamiaceae) grown by vegetable farmers in Ojo Local Government Area of Lagos State, Nigeria. Using grid method, 36 points were located to collect soil samples at 0–15 and 15–30 cm depths, while plant samples were also collected simultaneously. The contents of lead and cadmium in soil and plants were determined and results were subjected to descriptive statistics while the transfer factor (TF) was calculated. Lead ranged from 1.85 mg kg⁻¹ at the topsoil to 2.54 mg kg⁻¹ at subsoil. Cadmium varied from 0.99 mg kg⁻¹ at the topsoil to 1.41 mg kg⁻¹ at subsoil. Average TF were 0.21 for Pb and 0.35 for cadmium. Distribution of lead and cadmium increased in order leaf < stem < root indicating that the root of basil may be useful in bioremediation of metal-contaminated soils. Although, the levels of lead and cadmium contents in the basil leaf are lower than other parts, there could be accumulation of these metals through long-term consumption of the leaf.

Subjects: Agriculture; Agriculture Environmental Sciences; Agriculture and Food; Environment Agriculture

Keywords: contaminated soils; heavy metals' uptake; medicinal plant; *Ocimum basilicum*

ABOUT THE AUTHORS

The first author is a research scientist and holds a PhD in soil survey and land evaluation with specialization in soil quality. She has conducted studies on conventional soil survey, soil quality concept, and sustainable land use. The second author is a lecturer at a college of agriculture. The third author is a research scientist specializing in soil conservation. He has conducted studies on remediation of polluted and erosion affected soils. The last author is a research professor and a land evaluation expert. This study is very important because population increase has led to the intensification of land use and reduction in the quality and length of fallow. Therefore, no place should be allowed to get contaminated by heavy metals. There is also the need or concern for safe environment under agricultural land use and this informed the need to sustain land use without damaging the environment.

PUBLIC INTEREST STATEMENT

There is need to ensure that agricultural products are safe for all consumers. Indiscriminate consumption of heavy metal contaminated plants can be hazardous because of the tendency of accumulating heavy metals in the body. In this study, we evaluated the contents of two heavy metals in soil and parts of basil (a plant used as spice and medicine to cure certain ailments). It was discovered from the study that lead and cadmium concentration in the subsoil is greater than that of the topsoil. Also, the leaf of basil which is the edible part has the least content of lead and cadmium. This notwithstanding, care should be taken when consuming the leaf of basil because accumulation of these metals over time can be deleterious to human health. The root of basil which was found to contain the highest value of the metals can be used in bioremediation of heavy metal contaminated soils.

1. Introduction

Research into physical and chemical properties of soils has been focused on the requirements of farming and forestry and to an extent towards the understanding of natural ecosystems. However, there is need to focus on the urban environment, in which the majority of the population lives and comes into contact with the soil (Fraser, 2002; United States Environmental Protection Agency [U.S. EPA], 2011). Urban areas differ from rural ones in both the scale and intensity of human impacts. Urban agriculture is the practice of cultivating, processing, and distributing food in, or around (peri-urban) a village or city (Bailey & Nasr, 2000). Urban development coupled with the presence of industrial activities within urban areas leads to varying degrees of soil contamination with one or more materials. Pollution with heavy metals such as lead, arsenic, or cadmium is a serious concern because once these elements enter the soil they can persist for a long time (Marshall et al., 2003).

Together with other pollutants, heavy metals are discharged into the environment through industrial activity, automobile exhaust, heavy-duty electric power generators, municipal wastes, refuse burning, and pesticides used in agriculture. Human beings, animals, and plants take up these metals from the environment through air, water, and consumption of plants that have already absorbed them from the soil. Heavy metals have the tendency to accumulate in both plants and human organs (Dreshaj, Hidajete, Muzlijaj, Fekaj, & Beqiraj, 2013). However, some heavy metals as micronutrients (such as copper, nickel, chromium, and iron) are essential in very low concentration for the proper functioning of vital organs in the body. For example, iron is a component of hemoglobin and other compounds used in respiration.

Soils with elevated levels of heavy metals can have negative effects on human health because the metals in the soil have tendency of moving into the food chain through uptake by the plant root (Ozkutlu, Sekeroglu, & Kara, 2006). Medicinal plants play a major role in the health care sector of developing nations for the management of diseases. Thus herbal medicines have a prominent role to play in the pharmaceutical markets and health care sector of the twenty-first century. Medicinal plants or spices that are used as food or seasonings are called herbs or potherbs. A good example is sweet basil (*Ocimum basilicum*). Basil is a sweet herb used for fragrance and as a seasoning for food (Bown, 1995). It is generally known that basil is a household spice and also used for cure of certain ailments (Jena & Gupta, 2012; Khan, Khan, Hussain, Marwat, & Ashtray, 2008), therefore its consumption should be safe. Even though a lot of phytochemical and bioactivity studies have been carried out on a number of medicinal plants (Annan, Kojo, Cindy, Samuel, & Tunkumgnen, 2010; Jinadasa et al., 1997), not much has been reported on the heavy metal contents of this plant. This study therefore aimed at (i) determining the levels and amount of lead and cadmium transferred from the soil to basil plant, and (ii) to know if the contents of these metals in the soil and basil are above the permissible level for human health.

2. Materials and methods

2.1. Study site

This study was carried out in Ojo Local Government Area of Lagos State (Latitude 6° 26' N, Longitude 3° 12' E) Nigeria at a dedicated urban agricultural land cultivated by cooperative vegetable farmers under the Fadama Users Association of Nigeria. The site is located on about 30 ha of land within an industrial estate, where waste management is poor and household solid waste is dumped indiscriminately into drainage channels, while industrial effluents are discharged to the streamlets which eventually discharged to the streams and rivers.

The site is part of the Western Nigeria low land area described as being relatively flat to very gently undulating plain developed on sedimentary parent rock and Littoral deposits (Ojanuga & Isirimah, 1986). The dominant slope of the topography is 0–2% on the crest and 1–2% on the sides. The soil is an entisol classified as Psamentaquent. It is predominantly sandy and water table as at the time of this study was high (about 30 cm). The area enjoys a hot and humid tropic climate like the rest of southwestern Nigeria. The climate is characterized by seasonal rainfall, high temperatures, and high

humidity. The environment is noted for two distinct seasons of rainy and dry periods in a year. The dominance of the seasons is primarily controlled by two major air masses or wind currents. The southwest trade wind dominates over the area bringing about rainy season between March and November, while the northeast trade wind has greater influence between December and February, imposing dryness in the area. The southwest monsoon wind originates from the Atlantic Ocean; hence it is moisture laden and warm, bringing rains, while the northeast wind is cold, dry, and dusty. Its chilly influence in the months of December/January is often referred to as harmattan. The occurrence of these winds is controlled primarily by the North–South migration of the zone of demarcation between them, known as the Inter-Tropical Discontinuity. The movement, though usually gradual, is steady and consistent; hence, the regular pattern of rainfall and dry periods in the year. It directly and indirectly controls other climatic parameters like temperature, relative humidity, cloud cover, wind direction, speed, etc. The area is thus located in the humid zone, characterized by bimodal wet season, having a growing season of between 240 and 300 days (Ojanuga & Isirimah, 1986).

The site has been under cultivation for over 20 years and they practiced irrigation because the soils usually drain fast due to high sand particles. The farmers also make use of NPK fertilizer and poultry manure.

2.2. Soil and plant sampling

Using grid method at 20 m × 20 m, 36 sampling points were located and soil samples were collected at two depths (0–15 and 15–30 cm). Plant samples were also collected simultaneously at the 36 sampling points. The soil samples were air dried, crushed gently, and allowed to pass through a 2 mm sieve mesh for laboratory analyses. The plant (basil) parts were separated into leaf, stem, and root into properly labeled paper bags and oven dried at 65°C temperature for five days.

2.3. Soil and plant analyses

Lead and cadmium contents of the soils were determined by adding 10 ml of concentrated perchloric acid (HClO₄), 5 ml concentrated HNO₃, and HCl to 1 g of prepared soil sample in digestion tubes and left overnight in a fume cupboard. The filtrate of the digest was read for cadmium and lead concentration at different wavelengths and resonance. All other soil parameters (pH, particle size, exchangeable cations, available phosphorus, active carbon, and potentially mineralizable nitrogen) were determined using standard procedures (Day, 1965; Gugino et al., 2007)

The plant samples were analyzed by taking 2 g of grounded sample that was turned to ash in furnace at 500°C temperature for 5 h. About 10 ml of 1 N HCl was added and allowed to boil for 2–3 min, distilled, and made up to 100 ml mark with distilled water in a volumetric flask. From the extract, Ca, Mg, and the heavy metals (cadmium and lead) were read at different resonance and wavelengths on Atomic Absorption Spectrophotometer, Na and K were read by flame photometer, while P was read on spectrophotometer.

Descriptive statistics was carried out while mean values were separated

Calculation of transfer factor (TF): This was obtained by the following formula.

TF = Concentration of metal in plant

Concentration of metal in soil (Awode, Uzairul, Balarabe, Harrisson, & Okunlola, 2008)

3. Results

3.1. Soil

The mean, standard deviation, and range of properties of the topsoil (0–15 cm depth) and subsoil (15–30 cm depth) are shown in Table 1. The soil chemical properties varied slightly between the topsoil and the subsoil. The soil is slightly acidic with pH (H₂O) values ranging from 5.40 to 6.77 at

Table 1. Physical and chemical properties of the soil

	Sand	Silt	Clay	pH (H ₂ O)	pH (KCl)	Ca	Mg	K	Na	H ⁺	ECEC	AC	PMN	Av. P
(g/kg)				(cmol/kg)							(mg/kg)	(mg/kg)	(mg/kg)	
Topsoil (0–15 cm)														
Mean	835.2	101.6	63.2	5.98	5.06	2.26	1.47	0.17	0.47	0.11	4.37	0.82	3.17	43.81
SD				0.30	0.19	0.54	0.29	0.10	0.15	0.02	0.80	0.23	3.63	7.71
Max				6.77	5.65	3.72	2.07	0.60	0.91	0.14	6.27	1.33	15.00	61.43
Min				5.40	4.71	1.39	0.79	0.06	0.27	0.07	2.63	0.37	0.10	24.10
Subsoil (15–30 cm)														
Mean	835.2	101.6	63.2	6.00	5.11	2.21	1.45	0.16	0.46	0.11	4.28	0.78	3.37	46.98
SD				0.33	0.22	0.58	0.38	0.08	0.17	0.02	0.94	0.29	3.15	7.11
Max				6.75	5.70	3.90	2.11	0.46	0.86	0.15	6.30	1.26	12.00	61.43
Min				5.30	4.71	1.30	0.84	0.06	0.14	0.07	2.57	0.19	0.10	29.29

Keys: SD = Standard deviation, PMN = Potentially mineralizable nitrogen, Av. P = Available phosphorus, AC = Active carbon.

0–15 cm depth, and 5.30 to 6.75 at 15–30 cm depth. Cation-exchange capacity ranged from 2.63 to 6.27 cmol/kg at 0–15 cm and 2.57 to 6.30 cmol/kg at 15–30 cm with average values of 4.37 cmol/kg at 0–15 cm and 4.28 cmol/kg at 15–30 cm depths. Available phosphorus ranged from 24.10 to 61.43 mg/kg with an average of 43.81 mg/kg at the topsoil, and 29.29 to 61.43 mg/kg with an average of 48.98 mg/kg at the subsoil. Active carbon ranged from 3.70 to 13.30 g/kg with an average of 8.15 g/kg at the topsoil and 1.90 to 12.60 g/kg with an average of 7.80 g/kg at the subsoil indicating higher active carbon content at the topsoil than the subsoil. The value of PMN was slightly lower at the subsoil (with a range of 3.15 to 12.0 g/kg and average of 3.17 g/kg) than the topsoil (with a range of 3.63 to 15.0 g/kg and average of 3.37 g/kg). The values of sand, silt, and clay particles are the same at the topsoil and subsoil. They are 835.2, 101.6, and 63.2 g/kg, respectively.

The distribution of total lead and cadmium in the soil is shown in Table 2. Lead ranged from 0.75 to 4.38 mg/kg with an average of 1.85 mg/kg at the topsoil and 0.97 to 5.11 mg/kg with a mean of 2.54 mg/kg at the subsoil. For cadmium, the range is 0.27–1.89 mg/kg with a mean value of 0.99 mg/kg at the topsoil and 0.44–2.36 mg/kg with a mean value of 1.41 mg/kg at the subsoil. The values of cadmium both at the top and subsoil are higher than the reference value (0.7 mg/kg), while the values of lead are lower than the reference value (85.5 mg/kg). The contents of both lead and cadmium are higher at the subsoil than the topsoil.

Based on the root uptake of lead and cadmium, the TF were 0.08–0.36 with average of 0.21 for lead and 0.17–0.87 with a mean value of 0.35 for cadmium (Table 3).

Table 2. Distribution of lead and cadmium in the soil

	Topsoil (0–15 cm)		Subsoil (15–30 cm)	
	Lead	Cadmium	Lead	Cadmium
	(mg/kg)		(mg/kg)	
Mean	1.85	0.99	2.54	1.41
SD	0.96	0.46	1.11	0.52
Max	4.38	1.89	5.11	2.36
Min	0.75	0.27	0.97	0.44

Notes: Reference values of soil Cd and Pb are 0.7 and 85.5 mg/kg (Gjoka et al., 2008).

Table 3. TF of lead and cadmium from soil to the plant

	TF cadmium	TF lead
Mean + SD	0.35 ± 0.17	0.21 ± 0.09
CV (%)	49	41
Range	0.17–0.87	0.08–0.36

Key: CV = Coefficient of variation of set of values.

Table 4. Chemical and heavy metal contents of the different plant parts

Plant parts	Ca	Na	K	P	Mg	Cd	Pb
	(%)					(mg/kg)	
Leaf	0.28	0.18	1.33	0.07	0.26	0.04	0.06
Stem	0.39	0.27	1.51	0.13	0.37	0.09	0.12
Root	0.51	0.37	1.78	0.20	0.47	0.19	0.23

3.2. The plant

The contents of calcium (Ca), sodium (Na), potassium (K), phosphorus (P), magnesium (Mg), cadmium, and lead (Pb) in the leaf, stem, and root of basil are shown in Table 4. The highest contents of Ca, Na, K, P, and Mg were obtained in the root while the least concentration were found in the leaf (root > stem > leaf). The distribution of lead and cadmium follow the same trend with the lowest in the leaf and highest in the root.

4. Discussion

The essence of this study was to evaluate the content of lead and cadmium in soils in an urban farm sector, and predict the potential risk from consumption of plants raised with urban waste products. Medicinal plants/spices have been cited as a potential source of heavy metal toxicity to both man and animals since the consumers are not caring where they are being sourced from (Dwivedi and Dey (2002), Annan et al. (2010) and Dreshaj et al. (2013)). The most common heavy metals implicated in human toxicity include lead, mercury, arsenic, and cadmium, although aluminum and cobalt may also cause toxicity. Therefore, the World Health Organization recommends that medicinal plants, which form the raw materials for most herbal remedies, should be checked for the presence of heavy metals. However, majority of people, living in areas where these plants grow, harvest them locally for personal or family use without checking for heavy metal accumulation. The general notion that medicinal plants are safe and devoid of heavy metal toxicity could be misconstrued. A sure way of introducing heavy metal contamination into the soil and subsequently into medicinal plants is the use of metal yielding fertilizers. Farmers in the studied area are making use of poultry manure which can be a source of heavy metal contamination in the soil. This is in agreement with the submission of Street (2012) that heavy metals may be introduced into the soil and medicinal plants through contaminated agricultural resources and deliberate addition of metal producing fertilizers.

The contents of both metals (lead and cadmium) are higher in the subsoil than in the topsoil. This is at variance with report of Kachenko and Singh (2004), that heavy metal decreases significantly with depth. However, the soil of the site is Psamentaquent which is sandy in nature and highly porous, thereby enhancing rapid drainage and continual irrigation practice. The high porosity coupled with continual irrigation might have leached the cadmium and lead to lower depth. Meanwhile, the contents detected both at the top and subsoil was greatly lower than the values reported by Oluwatosin, Adeyolanu, Dauda, and Akinbola (2008). However, the cadmium content of the soil was above permissible level (0.7 mg/kg) set as world average concentration by Turekian and Wedepohl (1961) and 3rd International Symposium on Agriculture (Gjoka, Felix-Henningsen, Wegener, & Salilari, 2008). This implies that cadmium is present at higher concentration in the soil and which

perhaps result in high cadmium contamination of the plant. The value of lead, on the other hand, is less than the permissible value (1.85 mg/kg) as against the permissible level of 20.0 mg/kg in sedimentary soil quoted by Turekian and Wedepohl (1961) and 85.5 mg/kg set by Gjoka et al. (2008). Nevertheless, lead has been reported to have cumulative poisonous effect, thus, the concentration at any time does not need to be high before it will be harmful over a period of years (Donahue, Schickluma, & Robertson, 1971; Street, 2012).

The TF which is used to qualify the relative difference in bioavailability of the metals to plants or to identify efficiency of the plant species to accumulate a given metal is higher than what obtained by Awode et al. (2008) for pepper (*Capsicum annum*) (Table 3). Meanwhile, the acidic nature of the soil may have increased the availability of metals for the plant uptake. This is in agreement with the report of Kachenko and Singh (2004) that soil acidity and low carbon content in the soil increased availability of metals for vegetable uptake. Similarly, Hough et al. (2004) submitted that uptake of metals by plants depends on plant physiological factors and certain soil properties. This is the reason why it may be difficult to predict health risk from consumption of food crops. The TF of cadmium is higher than that of lead indicating that cadmium is easily accumulated by the plant than lead. The same trend was reported for cadmium over chromium and copper by Awode et al. (2008).

The concentrations of some nutrient elements (Na, Ca, K, P, and Mg) and the metals (cadmium and lead) in plant parts follow the trend of leaf < stem < root indicating that the least contents were found in the leaf which is the edible portion. Also, the contents of these two metals in the leaf part are lower than the Australia and New Zealand Food Standard (ANZFA) code (Kachenko & Singh, 2004). However, there is high tendency that those that are consuming the leaves either medicinally or as a spice may have accumulated cadmium beyond provisional tolerable weekly intake (PTWI) recommended by WHO (2007) because there may be indiscriminate consumption and the quantity consumed may not be put into consideration. Furthermore, it had been established that prolonged consumption of heavy metals such as cadmium and lead can cause deleterious health effects in humans (Jena & Gupta, 2012; Reilly, 1991). Also, for people below 50 kg body weight, too much consumption of basil (400 g basil per week) is not safe and people above this body weight of 50 kg must also be careful not to accumulate the metals to toxic level (WHO, 2007).

5. Conclusion

This study evaluated the contents of lead and cadmium in soil and *O. basilicum* plant parts in a populous urban farm sector. The potential danger of lead and cadmium accumulation from consumption of *Ocimum basilicum* grown at the study site was highlighted. In the soil, cadmium level was above the permissible level but lead was below the permissible level. The highest contents of both lead and cadmium were detected in the root of basil. However, the level of concentration of the metals is root > stem > leaf. The root of basil plant may however be used for bioremediation of heavy metal in metal contaminated soils. Although the levels of the metals in the leaf part of basil are below the permissible level, the cumulative poisonous effect of consuming the leaf does not need to be high before it becomes harmful over a period of time. Therefore, there is need to undertake total diet study on our food and herbal crops in order to increase our knowledge on the contamination of heavy metals and also to ensure that agricultural products are safe for all consumers.

Acknowledgment

The authors want to acknowledge the supports of management, field and laboratory staff of Institute of Agricultural Research and Training, Obafemi Awolowo University, Moor Plantation, Ibadan.

Funding

The authors received no direct funding for this research.

Competing interests

The authors declare no competing interest.

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Citation information

Cite this article as: Lead and cadmium contents in a medicinal plant/spice grown in an urban city of Nigeria, Olateju Dolapo Adeyolanu, Olalekan John Kadiri, Kayode Steven Are, Gabriel Akinboye Oluwatosin & Manuel Tejada Moral, *Cogent Food & Agriculture* (2016), 2: 1136016.

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