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SOIL HEALTH, OUR HEALTH: EFFECT OF PAINT EFFLUENT CONTAMINATED SOIL ON THE HEAVY METAL CONTENT OF OKRA (*Abelmoschus esculentus* Moench)

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ABSTRACT
A study was conducted at Michael Okpara University of Agriculture, Umudike to evaluate the growth and tissue metal content of *Abelmoschus esculentus* in soil which had been subjected to long term dumping of paint factory waste. Agronomic parameters stem girth, leaf length and plant height of Okra plant were measured at two week intervals, and after 12 weeks of growth, the soil, roots, leaves and fruit of okra were analyzed for cadmium, lead, zinc, iron and cobalt. The results showed that the growth of *Abelmoschus esculentus* was not significantly hindered by paint effluent contaminant. However, in comparison with plants grown in non contaminated soil, the concentration of lead (73.9 mg/kg) in Okra leaves was significantly high while the average concentration of zinc (59.2 mg/kg) in its roots was significantly high ($P<0.05$).The zinc and lead concentrations found in Okra fruit (74.11mg/kg and 81.92 mg/kg respectively) were also significantly high and the levels were above allowable limits in plant tissues (10 mg/kg for zinc and 0.2 mg/kg for lead), raising concerns for safe consumption of fruiting vegetables grown in paint effluent contaminated soil.

INTRODUCTION

Advances in industrialization and the attendant anthropological activities have led to environmental degradation and serious ecological imbalance globally, posing a major challenge (Koranteng – Addo *et al.,* 2011; Sharma a *et al.*, 2008). This is more so in developing countries like Nigeria where the occurrence of environmental contamination is directly related to continued increase in industrialization and poor waste disposal practices (Nwachukwu, 2013; Oluwatosin *et al.,* 2005).

Soil contamination generally arises from the discharge of industrial wastes to the soil, application of pesticides, percolation of contaminated surface water to sub surface strata, rupture of underground storage tanks, oil and fuel dumping, or leaching of wastes from landfills (Steinberg, 2011).The common environmental contaminants are petroleum hydrocarbons, solvents, pesticides, and other heavy metals. Heavy metals are metallic chemical elements which are natural constituents of the earth crust, a number of which are biologically essential (Omar and Al-Khashaman., 2004). However, there are also heavy metals like Arsenic (As), Cadmium (Cd), Chromium (Cr), Mercury (Hg) and Lead (Pb) which are non essential for plant growth, and are toxic even at low concentrations (Alloway, 1990a; Pulford, 2007).

The concern over soil contamination is heightened due to health risks emanating not only from direct contact with contaminated soils, but also the secondary contamination of water supplies and possible bioaccumulation of contaminants through the food chain (EFSA, 2009; USEPA, 2003). These chemicals are not only poisonous to humans but have also been found toxic to aquatic life (Novick, 1999; WHO, 2002). Contamination of air, soil and water by industrial effluents is often associated with heavy disease burden in humans (Tamburlini *et al.,* 2002). This is more so because contaminants like heavy metals are not biodegradable and tend to accumulate in organisms or through the food chain causing numerous diseases and disorders (Malakootian *et al.,* 2009; Ozer, 2007). There have been reports of bone diseases caused by cadmium toxicity as a result of feeding on rice irrigated with water which had been contaminated from mining and smelting (Graham and Farmer, 2007).

Paint industries rank among the most notorious in the discharge of effluents containing heavy metals, because paint manufacturing components include pigments, solvents, blotters and auxiliary additives which are made of heavy metals (Malakootian *et al.*, 2008). In general, most heavy metals pose a negligible risk of accumulating to toxic levels in agricultural food crops, but the transfer of certain elements like cadmium from soil to the edible portions of food crops is known to be significantly greater than for other elements. Okra (*Abelmoschus esculentus*), is widely cultivated in tropical, subtropical and warm temperate regions around the world (NRC, 2006). The plant is valued for its edible green seed pods, as the fruits are harvested when immature and eaten as vegetable. Invariably, crops will take up nutrients and contaminants from the soil in which they grow (Nwachukwu and Pulford, 2008), and the content of edible portions of a crop have been known to directly reflect soil contents. The objective of the study was to determine the effect of paint effluent on the growth and heavy metal content in the tissues and fruit of okra.

MATERIALS AND METHODS

Experimental layout and soil collection

The pot experiment was conducted in the greenhouse at Michael Okpara University of Agriculture, Umudike between December 2012 and March 2013. The experimental design was a 2 × 2 factorial, comprising two soil conditions- (contaminated and uncontaminated soil) and two cropping conditions- (planted and non - planted) in a Completely Randomized Design (CRD), with each treatment replicated three times. Bulk soil, which had been subjected to more than fifteen years of continuous discharge of paint effluents and waste was collected from a paint industry located in Ossah Ibeku, Umuahia North Local Government area of Abia state, Nigeria. Soil collection was in a semi circle fashion, at a distance of 5 metres around the effluent discharge point at the paint factory at a depth of 0 - 20 cm. Uncontaminated soil was also collected 50 meters upslope from the discharge point, and used as the control.The soil samples collected were air dried at room temperature, passed through a 2 mm sieve, bulked together and thoroughly mixed, after which 10 kg of the soil each was placed in 12 L plastic buckets. All plastic buckets were perforated at the base to allow for drainage.

Okra (*Abelmoschus esculentus*) variety V-35 seeds were sourced from National Seed Service, Umudike Centre, Abia State. Before planting the seeds, the soils were moistened allowed to stand for two weeks. Four seeds of Okra were sown into each bucket which was later thinned to three plants two weeks after germination. The plants were watered every other day throughout the period of crop growth, and weeding was done by hand-picking whenever weeds were observed. Routine soil analysis was carried out prior to planting and at the termination of the experiment 12 weeks after planting.

Collection of agronomic data and soil analysis

Data on plant height, stem girth and leaf length commenced 2weeks after planting and continued fortnightly until final harvest which was at 12 weeks after planting, in order to assess the effect of the effluent on the growth of Okra plant. Routine soil analyses carried out were particle size distribution by the hydrometer method (Bouyoucos, 1951); soil organic carbon (Black, 1965), exchangeable acidity and exchangeable Al as described by (Jackson, 1962); pH was determined in $CaCl_2$ and water and available P (Bray and Kurtz, 1945). Calcium and Magnesium was determined in the extract by EDTA titration while potassium and sodium were extracted with neutral NH_4OAc, and all cations read with a flame photometer (Jackson, 1962). Effective cation exchange capacity (ECEC) was determined as the summation of exchangeable Ca^{2+} + Mg^{2+} + Na^{+} + K^{+} acidity and the percentage base saturation was calculated using the formula:

Soil and plant tissue heavy metal analysis:

Soil cobalt (Co), cadmium (Cd), lead (Pb), zinc (Zn), and iron (Fe), were determined by hot digestion in Hydrochloric acid and read using Atomic Absorption Spectrophotometer. The roots and leaves and fruit of the *Abelmoschus esculentus* were analyzed for heavy metals by digesting in nitric acid and the extract read on an Atomic Absorption Spectrophotometer.

Statistical analysis: All data were subjected to analysis of variance (ANOVA) using GENSTAT Discovery 2005, while the significant mean values were separated using the Least Significant Difference (LSD) at P<0.05.

RESULTS AND DISCUSSION

A total of 8 heavy metals (zinc, Lead, Cadmium, Manganese, Iron, Cobalt, Nickel and Copper) were initially analyzed and from the results obtained, five of these metals (Lead, Cadmium, Cobalt, Zinc and Iron) were found to be above the critical limits (Table 1) of 100 - 400 mg/kg, 3-8 mg/kg, 25 - 50 mg/kg and 70 - 400 mg/kg respectively for soil values (Bowen, 1979).

The particle size distribution and chemical properties of the soil samples used for the study are shown in Table 2.

The textural class of soils used was sandy loam. Paint effluent contaminated soil had lower soil pH, being 5.38 in $CaCl_2$ and 5.50 in H_2O, while the uncontaminated (control) soil sample had an average mean pH of 6.06 in $CaCl_2$ and 6.30 in H_2O.The available P of study soils was far below the critical level of 15 mg/kg P for

$$\% \text{ base saturation} = \frac{\text{Summation of exchangeable bases}}{\text{ECEC}} \times 100$$

Table 1 Heavy metal levels in the soil at the onset of the study

Heavy metals(mg/kg)	lead	cadmium	zinc	iron	cobalt	nickel	copper	manganese
contaminated	170.00	89.50	113.91	31532.50	113.10	87.95	104.25	228.40
uncontaminated	83.30	53.10	112.79	23143.75	79.70	89.20	85.80	114.25

Table 2: Particle size distribution and chemical properties of soil used for the study

Soil properties	Mean values	
	Contaminated soil	**Uncontaminated soil**
%sand	64	68
%silt	17	21
%clay	19	11
Texture	SL	SL
pH($CaCl_2$)	5.38	6.06
pH (H_2O)	5.50	6.30
Av. P(mg/kg)	1.79	2.05
%O.C(g/kg)	0.7	7.3
%O.M(g/kg)	1.2	12.6
%N(g/kg)	0.6	0.9
Ex. Acidity(cmol/kg)	0.88	0.80
Calcium (cmol/kg)	32.80	5.20
Magnesium (cmol/kg)	8.40	2.40
Potassium (cmol/kg)	0.30	0.30
Sodium (cmol/kg)	0.40	0.40
Total exchangeable bases	41.9	8.3
E.C.E.C	42.78	9.10
%B.S	97.94	91.21

South-Eastern Nigeria, at 1.79 mg/kg for the contaminated and 2.05 mg/kg for the uncontaminated soils respectively. The low values of available P might be due to fixation of P by iron sesquioxides, which is known to occur under well drained and acidic conditions in the soil (Uzoho and Oti, 2004). Low levels of organic carbon was found in both the uncontaminated and paint effluent impacted soils used for this experiment, and this can be attributed to the environment of Eastern Nigeria which is characterized by high temperature and relative humidity conditions that favour rapid decomposition and mineralization of organic matter (Chikezie *et al.*, 2009).

Within the 12 weeks period the experiment lasted, *Abelmoschus esculentus* survived in spite of the elevated heavy metal levels in the contaminated soil (Table 3).

The germination period of *Abelmoschus esculentus* ranged between 2 to 3 days indicating that the metal levels in the soil did not hinder seed germination period (Adekunle *et al.*, 2010), and there was a steady increase in their plant height, stem girth and leaf length until towards the 8th week after planting. The plant height, stem girth and leaf length were nevertheless depressed by the paint waste contaminant in the soil, although the growth of plants in the uncontaminated (control) soil was better, there was no significant difference (Table 3)..

Reduction of plant height and biomass of *Abelmoschus esculentus* plant due to heavy metal contamination has been reported (Anoliefo *et al.,* 2000; Vwioko and Fashemi, 2005) and it is believed that metallic contaminants interfere with mitotic division in leaves. The accumulation of heavy metal in sensitive plant tissues has also been known to cause alterations in various vital growth processes such as photosynthesis and photosynthetic electron transport and biosynthesis of chlorophyll .(Moscquot *et al.,* 1996).

Table 4 shows the chemical properties of the contaminated and uncontaminated soil samples after 12 weeks of crop growth. It is known that the lower the pH of a system the more metals are released to the soil solution because of proton competition for exchange sites of clay minerals or organic matter or through proton promoted dissolution of soil minerals (Pulford, 2007). The pH of soil also affects the very process of metal uptake into the root of plants. Also, the retention of metals to root organic matter is weaker at low pH, resulting in more available metal in soil solution for root absorption (Clemente *et al.*, 2006).The initial low pH of the contaminated soil samples may have favoured the heavy metal uptake by the plant, (Casagrande *et al*., 2004).

Lead concentration in the leaves of *Abelmoschus esculentus* was significantly ($P<0.05$) higher than the control soil (Table 5). While the leaf content of Cd, Co Zn and Fe were elevated in contaminated soil, the levels were not significantly higher than those in non contaminated soil. It has been deduced that cadmium accumulation by different plant parts could

Table 3: Leaf length, stem girth and plant height of *Abelmoschus esculentus* during growth period.

	Weeks after planting	Leaf length(cm)	Stem girth(cm)	Plant height (cm)
Contaminated	2	3.9	0.9	11.2
	4	6.4	1.0	14.5
	6	8.4	1.2	15.9
	8	8.9	1.5	17.5
	10	9.1	1.6	17.7
	12	9.2	1.7	17.8
Uncontaminated	2	4.5	1.0	12.3
	4	7.6	1.4	16.1
	6	12.1	1.5	17.6
	8	14.4	2.0	19.2
	10	15.1	2.2	19.3
	12	15.1	2.2	19.3
	LSD	NS	NS	NS

Table 4: Chemical properties of study soils 12 weeks after planting.

Parameters	Contaminated soil	Uncontaminated soil	$LSD_{(0.05)}$
$pH(H_2O)$	6.13	6.16	0.16
$pH(CaCl_2)$	5.88	5.87	0.27
Exch.acidity(cmol/kg)	0.83	0.92	0.24
Magnesium (cmol/kg)	8.03	1.20	0.71
Sodium(cmol/kg)	0.47	0.30	0.09
Potassium(cmol/kg)	0.33	0.30	0.09
Calcium(cmol/kg)	47.40	8.90	3.92
Available P (mg/kg)	0.90	1.27	0.38
%Nitrogen (g/kg)	0.09	1.13	0.03
Organic carbon (g/kg)	1.15	2.04	0.41
Organic matter (g/kg)	1.98	3.52	0.70
TEB	56.23	10.70	3.73
ECEC(cmol/kg)	57.07	11.62	3.73
%BS	98.53	92.13	2.54

TEB = Total Exchangeable Bases, ECEC = Effective Cation Exchangeable Capacity, B.S = Base Saturation, Exch. Acidity = Exchangeable acidity, Available P = Available phosphorus.

reach a saturation level without the appearance of phytotoxic symptoms (Akinola and Ekiyoyo, 2006; Dong *et al.,* 2007). Therefore, cadmium contamination of the soil could remain undetected even when the plants were grown in the presence of consistently high level of cadmium. This poses even greater threat to food safety, as consumption of Cd contaminated rice has led to fatalities (Wang *et al.*, 2003).

The concentration of zinc in the roots of *Abelmoschus esculentus* was significantly ($P<0.05$) higher than the control (Table 6). Zinc often occurs in an easily soluble form in the soil and thus is readily available and can also occur mainly in the form of oxides and in combination with organic matter (Ramos *et al.,* 1999). Moreover, zinc has been found to be highly mobile, easily being translocated from roots to aerial parts of the plant, thus posing a threat where leaves are the edible portion of a crop (Nwachukwu and Pulford, 2009) Root concentration of lead, cadmium, cobalt and iron grown in contaminated soil were however not significantly different from those grown in uncontaminated soil (Table

Table 5 Heavy metal concentration in the leaves of *Abelmoschus esculentus*.

Heavy metals(mg/kg)	Lead	Cadmium	Cobalt	Zinc	Iron
Contaminated soil	73.9	3.57	18.4	128.0	558
Uncontaminated soil	11.8	2.95	17.1	108.0	369
$Lsd_{(0.05)}$	35.14	2.49	10.91	79.2	236.7

Table 6: Heavy metal concentration in the roots of *Abelmoschus esculentus*.

Heavy metals(mg/kg)	Lead	Cadmium	Cobalt	Zinc	Iron
Contaminated soil	114.2	3.89	9.0	59.2	556
Uncontaminated soil	99.0	3.49	8.1	20.0	442
$Lsd_{(0.05)}$	26.71	2.14	6.72	16.84	378.7

6).

The danger in the high concentration of metals in roots may lead to direct harm where root crops are consumed by humans, or plant roots can be eaten by livestock and other animals which are fed upon by humans. In either way, these metals can still get into the food chain (Akinola and Ekiyoyo, 2006).

Table 7 shows that Pb and Zn content in the okra fruit 12 weeks after planting in paint effluent contaminated soils were significantly high ($P<0.05$).

The bio-accumulation of zinc in plants has been shown by its elevated content in fruits and seeds, even where seeds and edible parts of vegetables were well protected from accumulation of other metals, confirming the mobility of Zn and its ability to be translocated from roots to shoots in the plant (Kidd *et al.,* 2007; MacFarlane and Burchett, 2002). Lead content in the okra fruit was also found to be significantly high ($P<0.05$), although many researchers have

Table 7: Heavy metal concentration in the fruit of okra 12 weeks after planting

Heavy metals	Contaminated	Uncontaminated	LSD 0.05
Lead	81.92	52.18	11.42
Cadmium	0.72	0.32	0.48
Iron	410.23	366.70	180.49
Cobalt	4.05	2.02	2.38
Zinc	74.11	27.21	25.63

found that the lead is immobilized in plant roots after absorption (Pichtel *et al.,* 1999). Cobalt and cadmium concentration in the okra fruit remained within safe concentrations which would suggest that they were not translocated to the okra fruits, given their toxic levels in paint effluent contaminated soil. Research has showed that rice grown in a cadmium-chromium-zinc contaminated paddy soil, concentrated up to 24 % of total plant biomass cadmium in the grain of rice (Wang *et al.,* 2003). The lead concentration in okra fruit was also above the allowable critical concentration in plants (Bowen, 1979). This would still make for grave concern even though the major pathway of Pb entering human tissues is via the blood stream either by inhalation or by diffusing through the skin rather than oral consumption.

CONCLUSION

Living plants will always take up available elements in the soil, whether such elements are essential or toxic. The ease of assimilation of zinc by Okra from soil, the subsequent transportation from root to leaves and the toxic levels found in Okra fruit show that soil contaminants can be highly phytotoxic. There is therefore, a real threat of heavy metal poisoning when contaminated food crops are consumed. A clean, healthy soil devoid of toxic substances will producehealthy and safe food crops, but contaminants in soil will translate to contaminants in edible portions of food crops. Maintaining soil health and avoiding the introduction of heavy metals into soil – plant systems has a direct bearing on human health.

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