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Research article

Assessment of some heavy metals in the surrounding soils and crops of West African ceramic industry

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Abstract: This study investigated heavy metal contamination of soil and some food crops including maize, sweet potato, and spinach around the vicinity of West African Ceramic Industry, Oguro village, Ajaokuta Local Government Area, Kogi State, Nigeria. Atomic Absorption Spectrophotometer was used to determine the concentration of heavy metals in soil and crops. The concentration of heavy metals in soil sample tested was lower than that of permissible limit of different International Standards. The lead-in crops were higher than that of the permissible limits of different International Standards. The study revealed that all the samples, except lead, did not exceed the Intentional Standards level in crops at Oguro village. Plant absorption of heavy metals from soil was in the order Cu>Pb>Ni>Cr>Cd. The study suggested that the ceramic industry is a source of pollution of heavy metals to the surrounding soils and consequently crops growing on the soils containing higher amount of metals that could be transferred into edible parts of the crops. The study area should be monitored regularly of these toxic heavy metals in soil, crops and other food materials to prevent excessive build-up in the food chain.
Keywords: Contamination - Absorption - Pollution - Permissible limit.

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INTRODUCTION

Heavy metals are hazardous contaminants in food and the environment and they are non-biodegradable having long biological half-lives (Haidarieh *et al.* 2013). In agricultural systems, metal contamination is of great concern due to their increasing trends in human foods and environment (Kachenko & Singh 2006). These metals can pose as a significant health risk to humans, particularly in elevated concentrations above the very low body requirements (Gupta *et al.* 2008). So, the metals must be controlled in food sources in order to assure public health safety (WHO 1995). An excessive amount of heavy metals in food causes a number of diseases, especially cardiovascular, renal, neurological, and bone diseases (Chailapakul *et al.* 2007). Heavy metals could reach food chain via biochemical processes and in the end threaten human health if it bio-accumulate in various trophic levels.

The contamination of soil and food crops by heavy metals is also a global environmental issue. They are ubiquitous in the environment through various pathways, due to natural and anthropogenic activities (Wilson & Pyatt 2007). In some special environmental conditions, metals may accumulate to toxic concentration which could cause ecological damages (Jofferies 1984, Freedman 1989). Onianwa & Fakayode (2000), Iyaka & Kakulu (2012), Babatunde *et al.* (2014) reported the contamination of soils by heavy metals as a result of anthropogenic activities from the vicinity of industrial areas. The pronounced industrial revolution in the last two centuries has increased the rate at which the environment is being contaminated (Stigliani *et al.* 1991). The accumulation of heavy metals such as lead and cadmium in the food chain can have adverse effects on human and animal health. Environmental pollution all over the world is a result of industrialization and urbanization which are responsible for discharging effluents that contains heavy metals (Chen & Chen 2001, Filazi *et al.* 2003). Cultivation of crops for human and livestock consumption on contaminated sites can cause the uptake and accumulation of heavy metals in the edible plant parts and then exert potential risk to humans and animal's

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health (Ikeda *et al.* 2000).

Intake of toxic metals in a chronic level through soil and vegetables has adverse impacts on humans, plants and the associated harmful impacts become apparent only after several years of exposure (Ikeda *et al.* 2000). Decreasing immunological defences in the body is a consequence of consuming heavy metal-contaminated food which can seriously deplete some essential nutrients such as intrauterine growth retardation, impaired psycho-social facilities, disabilities associated with malnutrition and high prevalence of upper gastrointestinal cancer rates (Iyengar & Nair 2000, Türkdoğan *et al.* 2003).

Agriculture is practice in Oguro village within the vicinity of the West African Ceramic Industry. Waste chemicals in liquid forms are being disposed of from the industry, and some of the chemicals go to the atmosphere in form of dust which will later settle on the soil. Heavy metals, except mercury, basically go into the atmosphere in form of aerosol and are deposited onto the soil through natural sedimentation and precipitation. So it is expected that the surrounding soils of this industry are not totally free from heavy metal contamination, and if the soil is contaminated, there is possibility that the plant will also take up those metals which in turn will be very harmful to human health.

In this study, we investigated the concentrations of Cu, Cr, Ni, Pb, Cd and As in both soil and food crops (maize, sweet potato and spinach); the food crops were selected because they are common foods consumed daily in Oguro village, and evaluated their contamination status with respect to EU, FAO/WHO, China food hygiene standard (CDPM 1994) and Indian standard guidelines (Awasthi 2000).

MATERIALS AND METHODS

Study area

The surrounding of West African Ceramics Company, Oguro village, Ajaokuta, was selected for this study. Ajaokuta (6º 40′ N, 8º48′ E) is a Local Government Area in Kogi State, Nigeria and a town within it on the left bank of the Niger River. The general climate is humid tropical, having distinct raining and dry seasons. Kogi State has a bimodal rainfall with the peak pattern occurring in July and September. The mean annual rainfall ranges from 1220 mm at Ajaokuta in the Central, 1560 mm at Kabba in the West to 1808 mm at Anyigba in the East. The temperature shows some variation throughout the year. The average monthly temperature varies from 17ºC to 36.2ºC. The relative humidity is moderately high and varies from an average of 65 – 85% throughout the year (Amhakhian *et al.* 2010).

Sample collection

Soil and crop samples were collected from the entire vicinity at the back of the industry within 0–500 m. Twenty-one (21) soil samples were collected randomly at a depth of 0–20 cm and locations were maintained at about 50 m distance from one sampling point to another, and samples were bulked together and a composite sample collected. Composite samples were also collected for each crop (sweet potato, maize, spinach). The samples collected were placed in labeled polythene bags and taken to the laboratory for preparation. The samples were collected in October 2018.

Sample preparation

Soil samples were air-dried, crushed and sieved through 2 mm sieve size for chemical analysis. The sieved soil was placed in polythene bag and taken to laboratory for analysis. The crop samples were properly dried in an oven at 90^{o}C. The dried samples were ground into fine particles and then placed in labeled polythene bags ready for heavy metal analysis.

Digestion of crop samples

The crop samples collected from Oguro village were digested according to Awofolu (2005). Ground crop samples measuring 0.5 g each of Sweet potato, Maize and Spinach were weighed into 100 cm^3 beaker, and a mixture of 5 cm^3 concentrated HNO_3 and 2 cm^3 $HClO_4$ were added and digested at low heat (<100ºC) using a hot plate until the content was about 2 cm^3. The digest was allowed to cool and then filter into 50 cm^3 standard flask. The beaker was then rinsed with distilled water using a washed bottle and then filters into 100 cm^3 volumetric flask and made up to 20 cm^3 mark. Each digest was carried together with the blank in triplicate for the determination of Cd, Cu, Pb, Cr, Ar & Ni.

Digestion of soil sample

The sample of soil was digested in other to carry out heavy metal analysis on them using the method of Ogunfowokan *et al.* (2009). One gram (1 g) of soil sample was digested in a Teflon cups with 30 cm^3 acqua-regia (HCl:HNO_3, 3:1) on a thermostatted hot plate at 150ºC. After about 2 hours of digestion, the Teflon cup with its content was brought down from the hot-plate to simmer. Then, 5 cm^3 HF was added to the mixture and heated further for 30 minutes. The Teflon cup with its content was then allowed to cool to room temperature and filtered. After which the filtrate was quantitatively transferred into 50 cm^3 volumetric flask and made to the mark with distilled water.

Sample analysis

Both the soil and crop samples were analyzed for heavy metals using Atomic Absorption Spectrophotometer. Two grams (2.0 g) of soil and 0.5 g of crop samples were weighed into a digestion flask differently; 10 mL of nitric perchloric acid (2:1) was added to the samples and digested at 150ºC for 1 hour 30 minutes. Two millilitres (2 mL) of HCl-distilled water (1:1) was added. The temperature was increased to 230ºC and further digested for another 30 minutes, removed from heat and allowed to cool. It was washed into a standard 50 mL volumetric flask and made up to the mark with distilled water. The amount of heavy metals in the sample was determined by Atomic Absorption Spectrophotometer (BUCK 210 VGP). The concentration of heavy metal was extrapolated from the calibration graph prepared.

RESULTS AND DISCUSSION

Table 1 showed heavy metal concentrations in soil and crops grown around the vicinity of West African Ceramic Company, Oguro village, Ajaokuta LGA, Kogi State. The concentrations determined for the metals are 5.36, 0.46, 0.48, 2.64, 0.026 and 0.0018 mg kg^{-1} in soil sample; 4.14, 0.31, 0.43, 1.50, 0.016 and ND mg kg^{-1} in Maize, 3.81, 0.34, 0.38, 0.48, 0.020 and ND mg kg^{-1} in Spinach and 3.96, 0.36, 0.41, 1.44, 0.041 and ND mg kg^{-1} in sweet potato for Cu, Cr, Ni, Pb, Cd and As respectively.

Table 1. Concentration of heavy metals in crops and soil.

Elements	Values (mg kg^{-1})				Permissible limit (mg kg^{-1})	
	Maize	Spinach	Sweet Potato	Soil	Soil	Crop
Cu	4.14	3.81	3.96	5.36	6–60[b]	40[d]
Cr	0.31	0.34	0.36	0.46	65[c]	2.3[b]
Ni	0.43	0.38	0.41	0.48	75–150[a]	1.5[a]
Pb	1.50	0.48	1.44	2.64	10–70[b]	0.3[b]; 0.2[f]
Cd	0.016	0.020	0.021	0.026	0.07–1.1[b]	0.1[b]; 0.3[c]
As	ND	ND	ND	0.0018	0.5[d]	0.2[e]

Note: Soil= [a]Indian standard Awasthi (2000) and European Union (2000); [b]FAO/WHO, codex general standard for contaminants and toxins in foods (1996); [c]World Health Organization (2000); [d] World Health organization (2004). Crop = [a]WHO/FAO (Codex Alimentarius Commission - Joint FAO/WHO (2007) and Indian standard Awashthi (2000); [b]WHO - Codex Alimentarius Commission, Joint FAO/WHO (2001) and codex alimentarius commission (1994); [c]European Union (2000); [d]FAO/ WHO - Codex general standard for contamination and toxin in foods (1996); [e]WHO - Codex alimentarius commission - 1991; [f]China food hygiene standard (CDPM 1994). ND= Not Detected.

Copper

The level of Cu in soil sample of the vicinity of the West African Ceramic Industrial site is shown in table 1. The Cu content in the studied soil from the vicinity of the ceramic industrial site is within the permissible limit according to FAO/WHO standard (1996), and the value for soils from ceramic industrial site in this study is higher than 2.44 and 4.21 mg kg^{-1}, respectively reported for form and fertilizer blending companies by Harami *et al*. (2004) in their study of heavy metal levels in industrial estate of Bauchi, Nigeria.

Copper concentration in crops ranged between 3.81 to 4.14 mg kg^{-1} (Table 1). The permissible limit according to WHO/FAO standard (1996) is 40 mg kg^{-1}. All the crop samples fall within the copper standard (40 mg kg^{-1}). Copper is a microelement that is essential in plant growth and occurs generally in soil, sediments and air. Cu content has been reported to differ according to the soil type and pollution source (Onder *et al.* 2007). The high concentration in some sites may be as a result of burnt vehicles along the major roads because copper is commonly found in electrical wirings.

Nickel

The Ni concentration of soil from the study area (0.48 mg kg^{-1}) is within the permissible limit according to EU standard - 2002. Peri *et al*. (2008) had reported higher values of Ni in their study than obtained in this study. Iyaka & Kakulu (2012) reported that the Ni contents in studied soil samples from the vicinity of two industrial sites (ceramic and pharmaceutical) decrease with increase in distance from the point source, which could be as a result of burning of fossil fuels to generate energy needed to sustain industrial activities which account for more than 80% of pollutant Ni.

The concentration of Ni in crops ranges from 0.38 to 0.43 mg kg^{-1}. The permissible limit by FAO/WHO is 1.5 mg kg^{-1}, the concentration values were all within the permissible limit. Nickel has been carefully evaluated to be an essential trace element for human and animal health.

Chromium, Cadmium and Arsenic

The concentrations of Cr, Cd and As in the soil were 0.46, 0.026 and 0.0018 mg kg^{-1} respectively, and it falls within the permissible limits. The values of Cr, Cd and As in crop samples ranged from 0.31 to 0.36, 0.016 to 0.021 mg kg^{-1} and ND respectively, which falls within permissible limits.

Lead

The Pb level in soil in the vicinity of the ceramic industrial site was 2.64 mg kg^{-1}. The concentration was within the permissible limit according to FAO/WHO (1996). Honk & Lock (2000) recognized ceramic industry as an important source of Pb and Cd pollution. Iyaka & Kakulu (2012) reported that obtained values for Pb from the vicinity of the ceramic industrial site shows that Pb levels generally decreased with distance from the factory, thereby suggesting dispersion from a point source.

The concentration of lead (Pb) in crops was found in toxic level. This varied from 0.48 to 1.50 mg kg^{-1}. The highest lead content was found in maize (1.50 mg kg^{-1}) while in spinach it was lowest in concentration (0.48 mg kg^{-1}). According to China food hygiene standard (CDPM 1994) the standard limit of lead for crops is 0.2 mg kg^{-1} while it is 0.3 mg kg^{-1} for WHO - Codex Alimentarius Commission (FAO/WHO 2001). It was found in all crops that lead concentration was more as compared to the permitted limit, so they are not suitable for consumption. In the study area, lead concentration that was found in the crops could be as a result of burning of fossil fuels to generate energy needed to sustain industrial activities.

Plants usually shows ability to accumulate large amounts of lead without change in appearance or yield, however lead is a toxic element that can be harmful to plants. In many plants lead accumulation can exceed several hundred times the threshold of maximum level permissible for human (FAO/WHO 2001). The introduction of lead into the food chain may affect human health and may cause disruption of the biosynthesis of hemoglobin and anemia, rise in blood pressure, kidney damage, miscarriages and subtle abortions, disruption of nervous systems and brain damage (Wierzbicka 1995). From the overall study of the heavy metals in crops it has been found that the results obtained for different parameters investigated in each category of crop samples were at normal levels except lead, which is harmful for human. Thus immediate actions are necessary to keep it within the permissible limit.

CONCLUSION

The results of heavy metal concentration in soil and crop samples indicated that the samples contained a substantially low level of the metals (Cu, Ni, Cr, Cd, As) as compared to FAO/WHO permissive levels. However lead (Pb) was found to be above the China food hygiene and FAO/WHO standards, and in very high concentrations Pb may pose danger to consumers of crops around the studied area. Except for As which was not detected in crop, other heavy metals determined were found in soil and crops grown around the vicinity of the studied area; with copper (Cu) having the highest concentration in crop samples, while cadmium had the lowest concentration. There is need for public awareness and monitoring of possible risks that could arise through the food chain from heavy metal contamination of soils.

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