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Total and Bioavailable Pb Content in Urban Paddy Rice Soils in Niger State, Nigeria

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Abstract

The total and plant available Pb content of forty composite soil samples from eight cultivated rice paddy soils from Niger State were investigated using Atomic Absorption Spectrophotometric technique, after their digestion with aqua regia and extraction with EDTA respectively. Varying Pb contents were obtained; the overall total Pb mean value was 12.6 ± 13.1 mg/kg, while the plant available Pb had mean concentration of 5.0 ± 3.1 mg/kg. Although the studied soil samples in this research were not polluted, they indicated a considerable Pb contamination that could serve as baseline data for lead level in paddy soils in Niger State. Hence, the need for constant monitoring of paddy soils to safe guide the possible risks that could arise due to bio - accumulation of Pb above the safety level and its consequence transfer through the food chain.

Keywords: Heavy metal, total lead concentration, plant available lead content, cultivated rice farmlands

1. Introduction

Urban soils are often contaminated (Mielke, 1994) with Pb, due to its ubiquitous nature in the environment (Nriagu, 1998). In urban areas, Pb contamination is generally higher in high traffic zones, concentrated industrial areas and older housing stock with lead containing paint (USEPA, 1998). Since Pb does not biodegrade or decay, concern for its significant role as a primary contributor in soil contamination in urban areas still persist, despite the fact that the addition of lead to gasoline and paint has been phased out in the 1970s (Clark *et al*., 2006). In urban gardens, fruits and vegetables grown in contaminated soils may also become contaminated as a result of plant uptake of Pb from soils or direct deposition of leaded dust onto plant surfaces (Rahlenbeck *et al*., 1999).

Pb is a toxic heavy metal whose extensive use has given rise to environmental contamination and implicative health challenges in many parts of the world. WHO (2009) documented that Pb exposure accounts for about 0.6% of the global burden of diseases, particularly in developing nations. ATSDR (2008) also classified Pb as the second most dangerous metal on the priority list of the U. S. Environmental Protection Agency. Acute exposures to Pb may cause gastrointestinal disturbances, hepatic and renal damage, hypertension and neurological effects that may consequently result to convulsions and death (IPCS, 1995).

Although, Laidlaw and Fillippelli (2008) reported that sampling strategies encouraged surface soil collection, when analyzing for soil Pb because of Pb accumulation in insoluble forms on the topsoil. However, proper understanding of the risks of soil Pb is particularly difficult in gardens used for growing food plants, because of the multiple ways by which soil Pb is ingested, inconsistent recommendations from various extension agencies, the fact that Pb testing services are not easily accessible and due to lack of standard EPA guidelines for Pb in garden soils used for growing food plants (Witzling *et al*., 2011).

Currently the use of acidic or chelating agents to dissolve trace metals from solids to solution has been on focus. Since most pollutant inputs in urban top soils are not silicate bound (Nomeda *et al*., 2004), a pseudo-total digestion methods of strong acids, that do not involve dissolution of silicates by hydrofluoric acid are used (Novak *et al*., 2003; Farmer *et al*., 1997). This type of analysis using aqua regia is considered adequate (Hseu *et al*., 2002; Chen and Ma, 2001; Loncaric *et al*., 2010), and is found useful in the estimation of the maximum element availability to plants (Vercoutere *et al*., 1995). Moreover, among the chelating agents used for heavy metal extraction from polluted soils, EDTA has been considered to be the most effective in solubilising soil –

bound Pb that are available for phytoextraction (plant available fraction) due to its strong complexing ability (Samani *et al*., 1998; Haag – Kerwer *et al*., 1999; Zeng *et al*., 2005; Nascimeto *et al*., 2006). Polettini *et al*., (2006) observed that EDTA can effectively remove 65 – 86 % Cd, Cu, Pb and Zn from polluted/contaminated soils.

This study is intended to study the urban paddy rice soils in order to evaluate the occurrence of Pb as a premise for future research on plant uptake and the possible consequence on human and animal health, through the food chain.

2. Materials and Methods

2.1 Locations of the Studied Area

Niger State with a total land area of 76,000 sq. km (about 9 % of Nigeria's total land area), currently has the largest land mass in Nigeria and lies between latitudes 8°20'N and 11°30'N and longitude 3°30'E and 7°20'E in the North central zone of the country. It has Minna as its capital city and three other major cities that include Bida, Kontagora and Suleja.

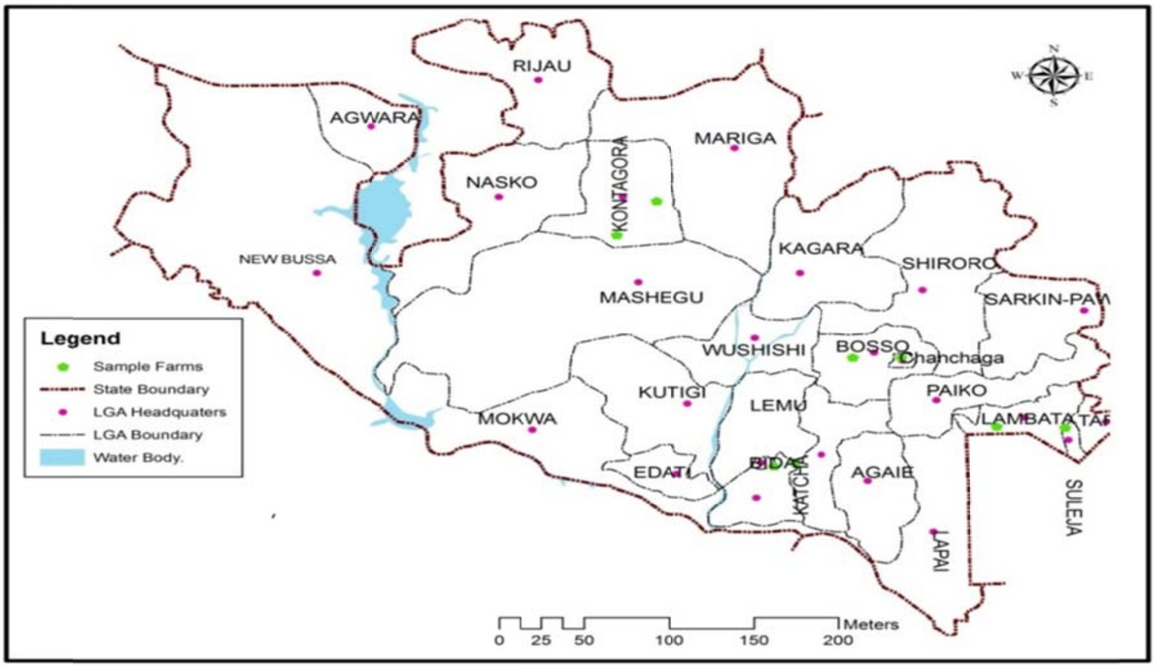

Figure 1. Map of Niger State Showing the Location of the Sampled Farmlands

2.2 Soil Sampling and Pre-treatment

The soil samples were collected from two farmlands located in each of major cities as indicated on the map (Figure 1). Samples were collected from 0 to 20 cm depth beneath the roots of uprooted cultivated rice plants using hand trowel (pre-cleaned with nitric acid and distilled deionized water) and stored in labeled polyethylene bags (Lokeshwari and Chandrappa, 2006). In each of the sampled farmlands, five well spread out points were identified and at each point, three sub-sample soils were collected within about 5 m distance to ensure through representation of each point. The three sub-samples from each point were then pooled together and homogenized to make composite of the sampling points. Thus, a total of 40 composite samples were prepared for analysis from the one hundred and twenty sub - samples collected.

After manual removal of debris, the soil samples were air-dried for a week in the laboratory at room temperature and then disaggregated by gently grinding in an agate (porcelain) mortar and pestle, sieved through a 2.0 mm stainless steel sieve and stored in well-labeled polyethylene bags for physical parameter analyses. Portions of each pre-treated sample were further pulverized to a fine powder, passed through 0.5 mm stainless steel sieve and stored in well-labeled polyethylene bags for organic carbon and Pb determination.

2.3 Analytical Methods

10.0 cm^3 of aqua regia was added to 1.0 g soil sample in 50 cm^3 beaker. The mixture was tightly covered with a glass slit (to enable refluxing) and allowed to heat on a hot plate in a fume hood at 98 – 100 °C for 2 – 4 hrs (until when cleared). The digest was allowed to cool and filtered through Whatman® No. 42 filter paper into 100 cm^3 volumetric flask. The beaker was then carefully rinsed and filtered through the residue into the content in the volumetric flask and made up to the mark with distilled deionised water. This was thereafter transferred to well - cleaned and labeled polystyrene sample bottles for Pb determination using Variant AA240FS – Fast Sequential Atomic Absorption Spectrophotometer.

10.0 cm^3 of 0.05 $moldm^{-3}$ Na_2EDTA solution was added to 2.0 g of air-dried soil sample in a 14 cm^3 centrifuge tube (with a tightly fitted stopper) and shaken on a mechanical shaker for 1 hr at a speed of 120 cycles min^{-1}. This was then centrifuged for 1 hr and filtered through Whatman® No. 42 filter paper into 25 cm^3 volumetric flask. The soil residue in the tube was then carefully rinsed with distilled-deionised water and filtered through the filter paper into the content in the 25 cm^3 volumetric flask and made up to mark. The extract was thereafter transferred into well - cleaned and labeled polystyrene sample bottles for plant available Pb determination using Variant AA240FS – Fast Sequential Atomic Absorption Spectrophotometer.

2.4 Quality Control

Routine laboratory quality control procedures were adequately adhered to in order to ensure precision and accuracy for this research. In the physical parameters and elemental determination quality control was monitored using 10% sample blanks and sample duplicates in the analysis.

3. Results and Discussion

3.1 Total Pb Content

Figure 2 shows the total Pb concentrations for the studied soil samples based on the city locations; the obtained results varied widely from 2.8 – 26.8 $mgkg^{-1}$ except for a sampling point at Kontagora with 83.8 $mgPbkg^{-1}$. The peculiar high Pb content at that point could probably be attributed to the effect of vehicular emission since that site was much closed to highway. The various mean values for all the locations (10. 4 $mgkg^{-1}$ – 17.4 $mgkg^{-1}$) are lower than the 100 $mgkg^{-1}$ recommended for garden soils where there is no need to be concerned about Pb exposure (Grubinger and Ross, 2011).

The average soil Pb concentration of 12.6 $mgkg^{-1}$ ± 13.1 $mgkg^{-1}$ (Table 1) for all the locations obtained from this study is lower than 18.12±14.96 $mgkg^{-1}$ reported by Umoru (2013) in her study of top soils from irrigated farmlands in Kaduna metropoly, Nigeria, probably due to lower vehicular emission from our sample locations. However, Payus and Talip (2014) documented lower Pb content range of 6.37 – 9.35 $mgkg^{-1}$ in their assessment of heavy metals in paddy soils of Kompipinan. Nevertheless, similar results to that obtained from this study were reported by Machiwa (2010) in his research on the paddy soils from wetlands of lake Victoria Basin, Tanzania.

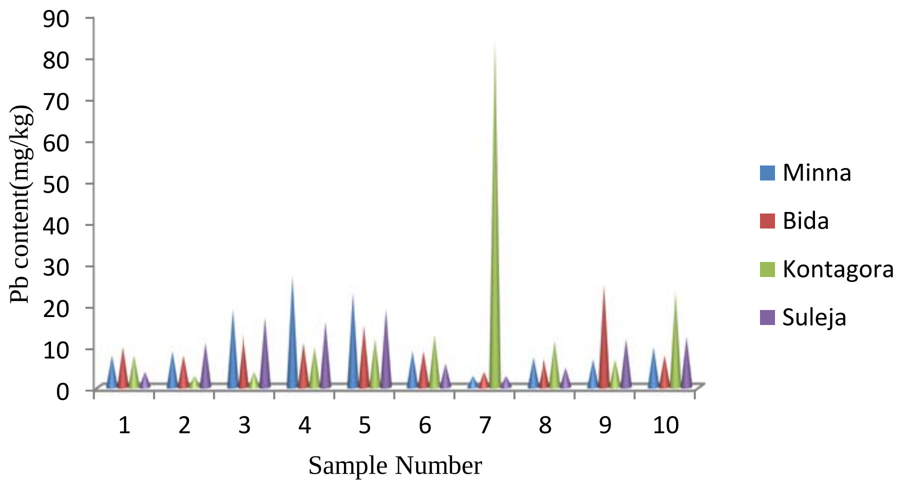

Figure 2. Total Pb contents in the studied soil samples

3.2 Plant Available Pb Content

Figure 3 shows the plant available Pb concentrations for the studied soil samples based on the city locations. The overall plant available Pb contents from all the sampled soils ranged between 1.3 and 14.8 mg/kg with mean value of 5.0 ± 3.1 mg/kg (Table 2). The obtained results generally indicated lower values for plant available Pb contents than those obtained for total Pb contents in this study. Very much higher bioavailable Pb content had been reported for paddy soils of Guangzhou Province in China by Shu (1997). Moreover, the plant overall plant available Pb concentration is also shown in Table 2 as a percentage with respect to the total content in soil.

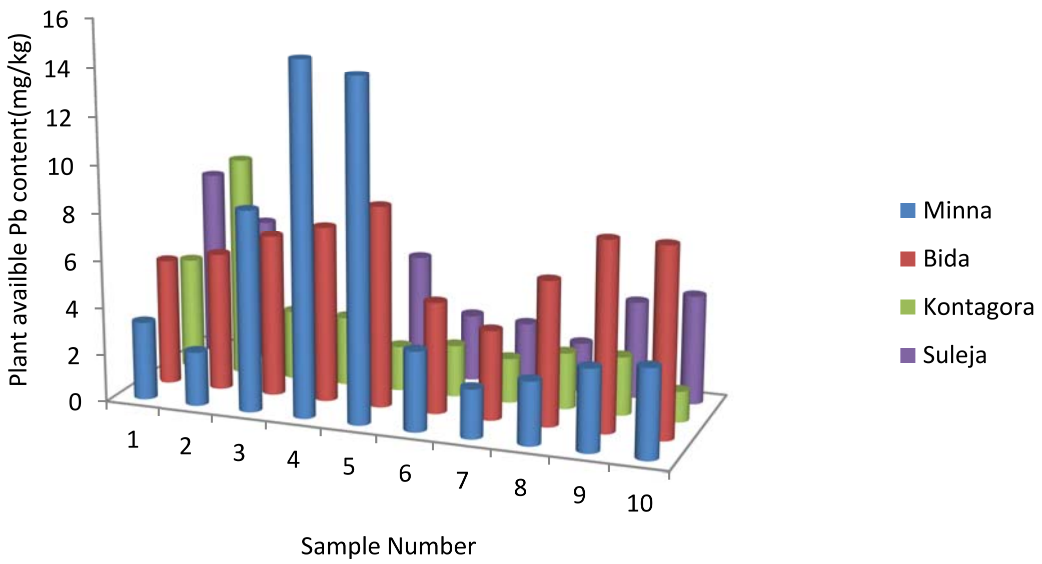

Figure 3. Plant available Pb contents in the studied soil samples

Table 1. Range and Mean values for the total and Plant available Pb contents (mg/kg)

Location		Minna	Bida	Kontagora	Suleja
Total	Range	2.8 – 26.8	3.8 – 24.8	2.8 – 83.8	2.8 – 18.8
	Mean ±SD*	12.1±7.7	10.8±5.8	17.4±24.0	10.4±5.8
Plant available	Range	2.1 – 14.8	3.8 – 8.5	1.3 – 9.3	2.1 – 7.9
	Mean ±SD	5.9±4.9	6.4±1.6	3.2±2.3	4.5±1.8

*Standard deviation

Table 2. Range and Mean values for all soils (mg/kg)

Total	Range	2.8 – 83.8
	Mean ±SD	12.6 ±13.1
Plant available	Range	1.3 – 14.8
	Mean ± SD	5.0 ±3.1
	% of total	39.7

4. Conclusion

Though still at very low levels of insignificant concern, Pb was found to be present in all the rice paddy soils of this study. However, Iyaka and Kakulu (2009; 2012) had reported no detectable Pb contents in background level of all their control soil samples in the study of urban agricultural soils in Niger State, Nigeria. Thus, the obtained results from this study signify accumulation of Pb above the background level for paddy soils locations of this research in Niger State. Furthermore, high concentrations of Cd, Pb and Hg have been identified with reduction in soil fertility and agricultural output (Lokhande and Kalkar, 1999). Hence, the need for constant monitoring of agricultural/paddy soils to safe guide the possible risks that could arise due to bio - accumulation of Pb above the safety level and its consequence transfer through the food chain.

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