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EVALUATION OF RISK ASSESSMENT FACTORS AMONG SELECTED METALS IN ROADSIDE GROWN CEREALS OF THE SUDAN SAVANNA ECOLOGY OF NIGERIA.

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ABSTRACT

Phytoaccumulation of metals (Cd, Cr, Cu, Pb, Zn) in roadside grown wheat and maize varieties (Pavon-76, Siettecerros, Zea mays L. and Zea mays everta L.) and the toxicity and phytoremediation capability of the plants was investigated. Four sampling sites, roadside (SU 1, SU 3) and distant sites (SU 2 and SU 4) were selected by principle to represent the level of pollution near major traffic routes and were the reference sampling points. Whole plant metal levels of the four crops were determined using the multi-elemental technique- Energy Dispersive X-ray Fluorescent (EDXRF) and double beam AAS at A.B.U Zaria. Plant uptake factor (PUF), soil-plant transfer coefficient (TC) and translocation factor (TF) was computed for each metal. Pearson correlation analyses between the risk assessment factors of the metals were evaluated. Results revealed a positive significant ($P<0.05$) relationship between PUF/TC and PUT/TF for Cr and Zn in Pavon-76, PUF/TC for Cr and Zn in the two species of Zea mays L. and Cu in Siettecerros indicates atmospheric inputs and special ability or strong selective ability of each of the crops to accumulate certain metals. The inverse correlation between PUF/TC, PUF/TF and TC/TF among the metals indicates the proximity of SU 1 to the major highway, influence of traffic density, atmospheric inputs and geological material and a combination of other factors. This study reveals the potentialities of these varieties of Wheat and Maize which are terrestrial higher plants as accumulators of metallic elements and phytoremediators of roadside soil pollution.

Keywords: Phytoaccumulation, metals, Pavon-76, Siettecerros, Zea mays L, Zea mays everta

INTRODUCTION

Heavy metals in high concentrations can cause severe phytotoxicity and may have significant influence on the evolution of tolerant plant populations (Eisa, 2009). Accumulator plants are usually indigenous to a particular type of soil or parent rock and may prove to be valuable geobotanical indicators for mineral deposits (Baker and Brooks, 1989). Another potential use of accumulator plants is in indicating anthropogenic pollution, since few species of accumulator plants are capable of colonizing ground contaminated with high concentration of heavy metals (Baker and Brooks, 1989). Metals cannot be degraded but get accumulated by plants. Plants that have been used in phytoextraction include Alpine Pennycress (T. caerulescens L.), effective in Zn2 +, Cd2 +, and Ni2 + hyperaccumulation (Milner and Kochian, 2008), Indian mustard (B. juncea), Serpentine endemic shrub (Alyssum sp.), and Astragalus racemosus are the most known natural hyperaccumulators (Chatterjee et al., 2013). B. juncea (Indian mustard) can accumulate Cd, Pb, Cu, Cr(VI), Zn, Ni, B, 90Sr, and Se (EPA, 2000; Nanda Kumar et al., 1995; Raskin et al., 1994; Salt et al., 1995). Therefore, it is possible to identify metal-tolerant plant species from natural vegetation in field sites that are contaminated with various heavy metals (Nazir et al., 2011). Hyperaccumulation of metals have been found in temperate as well as tropical regions throughout the plant kingdom, but is generally restricted to endemic plant species growing on mineralized soil and related rock types (Baker et al., 1989). Hyperaccumulation is an indigenous trait at the species level, being ubiquitous in all populations (Kumar et al., 2016). In the previous decades, around 500 plant species were reported as hyperaccumulators, which includes, 101 families including asteraceae, cyperaceae, brassicaceae, caryophyllaceae, fabaceae, cunouniaceae, flacourtiaceae, poaceae, lamiaceae, euphobiaceae, and violaceae (Kramer, 2010). The list includes several plant species viz., Thlaspi sp. (Baker et al., 1994), Brassica sp. (Blaylock et al., 1997; Huang et al., 1997), Alyssum sp. (Kramer et al., 1996), etc. Generally, indigenous varieties are favored as they have acclimatized to native conditions and seasonal cycles. In some cases, some exotic plant varieties may be preferred for the extraction of specific metals (USEPA, 2000; Bauddh et al., 2021). Some specific criteria have been adopted for selecting plant species which includes (i) must tolerate the level of metal present at the site; (ii) must accumulate, translocate and uptake specific metal adequately; (iii) should have high growth rate and biomass yield; (iv) must tolerate extreme environmental conditions like shortage of water (drought) or standing water, and acidic/basic or saline soil; and (v) the availability and preferred habitat (terrestrial, aquatic, semi-aquatic, etc.) of the plant must be considered (Bauddh, 2021). This concept was initialized by Baker et al. (1991) for Cd and Zn phytoextraction. Transfer factor from soil (TFS) is a key selection criterion for the appropriate hyperaccumulator plant. TFS is the ratio of the concentration of metals present in soil and parts of the plant. The TFS value of ≥ 1 indicates higher metal accumulation in plant parts compared to soil (Barman et al., 2000). Biomass production is another major determining factor for selection of plant species or variety for phytoremediation. Generally, the hyperaccumulators are found to be endemic to metalliferous soils called "strict metallophytes" that cannot survive without metalliferous soil, whereas various "facultative metallophytes" can survive on nonmetalliferous soil, even though they are ubiquitous on metal-enriched habitats (Kumar et al., 2016). Hyperaccumulation is an indigenous trait at the species level, being ubiquitous in all populations (Kumar et al., 2016). Hyperaccumulation depends on the plant species, soil physiochemical properties (pH, cation exchange capacity, organic matter content, electrical conductivity (E.C)), and different types of heavy metals (Van der and Reeves, 2015; Chaudhary and Khan 2016). In the application of terrestrial plants for soil remediation, metal uptake and translocation efficiency play an important role in achieving hyperaccumulation along with the capacity to tolerate the metal toxicity. Uptake efficiency is directly related to metal concentrations in the soil (Shukla andSrivastava, 2019). The research on terrestrial plants has also yielded a number of potential accumulators that could find successful application in the field (Shukla andSrivastava, 2019). Many researchers have reported the hyperaccumulation of heavy metals in some important plants. For instance, Arsenic in Pteris vittata, Arabidopsis bisulcatus; Copper in Eichhornia crassipes, Euphorbia macroclada; Chromium in Phragmites australis, Zea mays L. Cv Ganga 5; Manganese in Phytolacca Americana; Nickel in Berkheya coddii, Alyssum and Thlaspi; Selenium in Astragalus racemosus, Cardamine hupingshanesis; Titanium in Iberis intermedia; Zinc in Sedum alfredii, Euphorbia macroclada (Chaudhary and Khan, 2016).

Heavy metals are found in all kinds of soils, rocks and water in terrestrial and freshwater ecosystems. The very low general level of their content in soils and plants as well as the definite biological roles of most of them makes them microelements (Lacatusu, 1998). They occur in typical background concentrations in these ecosystems. However anthropogenic releases can result in higher concentrations of these metals relative to their normal background values. When these occur, heavy metals are considered serious pollutants because of toxicity, persistence and nondegradable conditions in the environment, thereby constituting threat to human beings and other forms of biological life (Tam and Wong, 2000; Yuan et al., 2004; Nwuche and Ugoji, 2008; Aina et al., 2009; Mohiuddin et al., 2010).

The soil-plant interface acts as a barrier that limits transmission of many heavy metals through the soil-crop-animal food chain, with the exception of Cd, Zn, Mo, and Se. Heavy metal pollution of soil entails plant uptake causing accumulation in plant tissues and eventual phytotoxicity and change of plant community (Ernst 1996; Zayed et al., 1998; Gimmler et al., 2002). The mechanism of uptake of trace elements by plants is essentially by root uptake and by foliar absorption, including deposition of particulate matter on the plant leaves. A convenient way for quantifying the relative differences of bioavailability of metals to plants is the transfer quotient. The transfer quotient for Cd and Cu were higher than other for metals, such as Pb and Fe (Khan et al., 2008). The higher transfer quotient of heavy metal indicates the stronger accumulation of the respective metal by that vegetable. Transfer quotient of 0.1 indicates that plant is excluding the element from its tissues (Thornton and Farago,1997). Khan et al., (2009) also argued that the greater the transfer coefficient, especially for values than 0.50, the greater the chances that vegetables will be subject to metal contamination by anthropogenic activities and so the need for environmental monitoring of the area will be required (Sponza and Karaoglu, 2002). A risk for contamination of food chain may arise when heavy metals accumulate in plant tissues to concentrations above the admitted threshold level, which is considered a threat to humans or animals feeding on the same crops. The capacity of certain plant species to concentrate heavy metals within their tissues also enhances the risk for contamination of food chain by concentrating heavy metals in certain tissues or organs (Salt, 1998; Anongo et al., 2015). Cereals were among the first domesticated plants used for food long before the beginning of recorded history (Kochhar, 1986). The prominence of cereals as food plants is attributed to their great adaptability permitting their successful colonisation in every type of ecological habitat, their relative ease of cultivars and tillering habit giving higher yields per unit area and dry and compact grains that can be easily handled, transported and stockpiled without undergoing spoilage and good nutritive value (Kochhar, 1986). Wheat, maize and rice which are called the staff of life because of their worldwide consumption have also been extensively used in many other researches with scarce information on their utilization for phytoremediation researches. Maize is preferred for cultivation and research for five major reasons namely 1) tolerance to specific heavy metals; 2) adaptation to soil and climatic characteristics; 3) fast growth of the plant; 4) heavy metal uptake capability; and 5) spatial fittings of roots of pollution distribution (Keller et al., 2003; Kalisova-Spirochova, 2003), which agrees with the specific criteria for selecting potential plant species that could be used for extracting heavy metals. Similarly, wheat being a temperate crop is known to have the broadest adaptation among all cereals has such phytoremediation potentials. The high heavy metal levels in the plant tissues of the dry season irrigation farming of the commonly grown varieties of wheat and maize at Kadawa, Kano State necessitated further research on the transfer of these metals into the food chain.

Given the foregoing, it is imperative to continue to conduct research on heavy metals and their impacts on the environment and propose ways by which the negative impacts can be mitigated. Therefore, this research was undertaken to identify and ascertain the relationships among the toxicity factors or risk assessment factors (PUF/TC, PUF/TF, TC/TF) and to evaluate the possible health risks to humans through food chain transfer.

2. MATERIALS AND METHODS

The selection of sampling sites and sampling units were by principle to represent the level of pollution in regions and towns with highest level of pollution, and also determined by possible pollutants at specific regions of interest (Misurovic, 1998). This study being an ecotoxicological research, all sampling sites were selected by principle to represent the level of pollution near major traffic routs and were reference sampling points (Misurovic, 1998). The bulk of the land space of Kano state is classified as the Sudan Savannah and a small portion of Sahel Savannah in the extreme north-eastern tip of the State (Abba,1991).The study area located in rural setting was chosen because it was devoid of any industrial, commercial and residential activities except the presence of the major highway – Kano-Zaria Highway, in order to assess trace metal levels in the crop plants due to atmospheric pollutants.

The research was conducted at Kadawa across the southern Sudan savannah zone of Kano State. The global positioning system (GPS) was used in recording the coordinates of the sampling units and geographical information system (GPS) was used to locate the map of the investigated sites. Table 1 shows the latitudes and longitudes readings of the sampling sites. Two sampling units SU 1 (Pavon-76 farm) at a distance of 50metres and SU 3 (yellow maize farm) at a distance of 100metres from the Kano-Zaria Highway respectively represented the experimental site, Doruwa Salau. Doruwa Salau has minimal residential and commercial activities and at close proximity to the highway at a distance of 345.79metres with extensive cultivation of rice, maize, millet, guinea corn, cowpea, garden egg, water melon and wheat along the roadside. The site had an average daily traffic density of 19,288, being the main exit from Kano State to various major towns of the country. At the Irrigation Research Station (IRS), the control site, two sampling unit SU 2(Siettecerros) at a distance of 1934.61metres and SU 4(popcorn) at a distance of 2184.61metres from the Kano-Zaria Highway were selected. The control site has been extensively used by private institutions, government researchers and both corporate and international research institutes and had an average daily traffic density of 3. Both sites are significant for dry season (irrigation) farming and have irrigation channels connected to the Hadejia – Jama'are River Basin Dam which empties into the Tiga dam that provides water for dry season irrigation of farmlands within and outside the irrigation research station, Kadawa.

A total of 288 plant samples and 208 corresponding soil samples were collected from four sampling units. Four crops namely Triticum aestivum – wheat (Pavon- 76 or Samwhit-6) and Zea mays - yellow maize (2:95 TZEE- Y), Triticum aestivum – wheat (Siettecerros or Samwhit-5) and Zea mays everta – popcorn were collected in a complete randomized block design setup. Four replicate samples each of leaves, stems and roots of the four crops were obtained at six selected growth stages namely 15 days (germination or seedling), 30 days (tillering), 45 days (shooting and booting), 60 days (earring or heading), 75 days (flowering and grain formation) and 90 days (maturity). Plant samples from both maize and wheat were harvested forthnightly according to the growth stages rather than by calendar days because the growth rates of the cultivars were slightly dissimilar. The leaves, stems and roots each of the four crops were placed under running tapwater to washed off soil particles, separated and placed in large paper bags to air-dry at room temperature and later ground using a grinding mill model Foss Cyclotec TM 1093 based on TecatorTM technology. The ground plant samples were then well packaged in readiness for laboratory analyses. The soil samples were collected in triplicates using a soil auger at the maximum sampling depth of 25cm and taken to the laboratory where they were air-dried and grounded into smooth powder using a porcelain mortar and pestle. The trace metal contents of the four crops and the corresponding soil samples were determined. The concentrations of Cr, Cu and Zn were determined using the multi-elemental technique-Energy Dispersive X-ray Fluorescent (EDXRF) at Center for Energy Research (CERT), while the concentrations of Cd and Pb were determined using the double beam spectrophotometer at National Animal Production Research Institute (NAPRI), Ahmadu Bello University, Zaria. The data for trace metal analyses was used to work out the risk assessment factors namely soil-plant transfer factor (TC), plant uptake factor (PUF) and translocation factor (TF). TC was calculated.

$$TC = \frac{\text{Content of heavy metal in plant (mg•kg-1)}}{\text{Content of heavy metal in soil (mg•kg-1)}}$$

PUF = Cp/Cso, where, Cp and Cso are metal concentrations in aerial parts of the plant (μg g-1) and in soil (μg g-1), respectively.

TF = Cs/Cr, where, Cs and Cr are metal concentrations (μg g-1) in the shoot and root, respectively. In all cases, a greater toxicity factors.

than unity value indicates anthropogenic contamination, while a ratio close to unity or less than one indicates natural sources. Pearson correlation coefficient analysis was used to investigate the relationship among the

3. **RESULTS AND DISCUSSION**

Coefficient analyses between PUF/TF, TC/TF and TC/PUF for Cd, Cr, Cu, Pb and Zn are shown in Table 2.There was positive significant relationship ($p < 0.05$) between the PUF/TF for Cr in Pavon-76 and Cu in Siettecerros. The PUF and TF signify the ability of plant to accumulate trace metals (Lou, 2012, Kumi et al., 2013). Transfer factors can be used to estimate a plant's potential for phytoremediation purpose. According to Baker et al., 1994, Brown et al., 1994, Wei et al., (2002) and Sasmaz et al., (2008), crops absorbed and transport metals from the soil, and stored them in the aerial plant parts. However, in contrast to this research, the existence of a relationship between PUF and TF for Cr and Cu (Pavon-76 farm closest (345.79m) to the Highway-SU 1 and Siettecerros farm at distance of 1934.61m from the Highway-SU 2) indicates special ability of the crop to absorb and transport Cr and Cu from the polluted atmosphere as well as storing them in the aerial plant parts resulting to higher concentration of metals in the leaves. Cr is used as corrosion inhibitors, for chrome-plated household, traffic and industrial materials while Cu is used as components of vehicle lubricating oils and vehicle engines.

Also there was significant positive relationship between PUF/TC for Zn in Pavon-76, for Cr in Zea mays L. and Zn in (yellow maize) and Zea mays everta L.(Table 2). The significant relationship between the TC/PUF for Zn and Cr in T. aestivum var. Pavon -76 farm closest (345.79m) to the Highway (SU1), Zea mays L.- yellow maize farm at distance of 345.79m from the Highway (SU 3) and Zea mays everta L. - popcorn farm farthest from the Highway at a distance of 2184.61m (SU 4) suggests that the levels of Cr and Zn in the crops came from both the atmosphere and the soil as earlier mentioned.

The non – existence of a significant relationship between the TF/TC (Table 2) shows that a larger percentage of the stem trace metal levels in the two cultivars each of Triticum aestivum and Zea mays L. could be of atmospheric origin. There were no values for correlations between TC/PUF and PUF/TF in Siettecerros, yellow maize and popcorn for Pb. Soil Pb was not detected during the trace metal analysis, which was the reason for no PUF values (Table 1) (See Appendix A, B, C and D).

Table 1: Soil Pb at the four Sampling Units at Kadawa

SAMPLING UNITS	**SOIL PbLEVELS BEFORE SOWING (mg/kg)**	**AFTER SOWING (mg/kg)**
SU 1	40	360
SU 2	80	80
SU 3	160	360
SU 4	40	ND

KEY

SU 1 = Wheat (Pavon-76) on Doruwa Salau at close proximity to the Kano-Zaria road
SU 2 = Wheat (Siettecerros) at the Control Site (Irrigation Research Station-IRS), Kadawa
SU 3 = Yellow Maize on Doruw aSalau at close proximity to the Kano –Zaria road
SU 4 = Popcorn at the Control Site (Irrigation Research Station-IRS), Kadawa

TABLE 2: CORRELATION COEFFICIENT ANALYSES BETWEEN PUF/TF, TC/TF AND TC/PUF

Risk Assessment Techniques	**Sampling Units**	**Heavy Metals**				
		Cd	**Cr**	**Cu**	**Pb**	**Zn**
PUF/TF	SU 1	0 .4737	0 .8210*	0. 3377	0. 2345	0. 2114
TC/TF	SU 1	0 .1090	0. 7204	-0. 5322	-5. 3895	0. 1473
TC/PUF	SU 1	0 .5356	0. 4695	-0. 0797	0. 9712 *	0.9958*
PUF/TF	SU 2	-0 .5926	0. 2925	0. 8909*	ND	0. 6699
TC/TF	SU 2	-0 .4537	0. 1725	0.3505	0.5206	0. 2849
TC/PUF	SU 2	0. 6858	0. 2912	0. 2336	ND	0. 6026
PUF/TF	SU 3	0. 1230	-0. 8058	-0. 6065	ND	-0. 4492
TC/TF	SU 3	-0. 3594	-0. 7316	-0. 9082*	-0. 2960	0. 2560
TC/PUF	SU 3	-0.0317	0. 9140*	0. 7534	ND	0. 8915*
PUF/TF	SU 4	-0. 2145	-0. 2675	-0. 0124	ND	0. 4699
TC/TF	SU 4	-0. 6020	-0. 0642	-0. 0985	-0. 5950	0. 4731
TC/PUF	SU 4	0. 7817	0. 4285	0. 6257	ND	0. 9986*

*0.05

PUF = Plant Uptake Factor
TF = Translocation Factor
TC = Soil-plant transfer coefficient
SU 1 = Wheat (Pavon-76) on DoruwaSalau at close proximity to the Kano-Zaria road
SU 2 = Wheat (Siettecerros) at the Control Site (Irrigation Research Station-IRS), Kadawa
SU 3 = Yellow Maize on DoruwaSalau at close proximity to the Kano –Zaria road
SU 4 = Popcorn at the Control Site (Irrigation Research Station-IRS), Kadawa

The correlation coefficients analyses between PUF/TF, TC/TF and TC/PUF for individual metals (Cd, Cr, Cu, Pb and Zn) are shown in Table 2. There was inverse correlation between TC/TF, PUF/TF and TC/PUF for certain metals at the four sampling sites (Table 2) reflecting that the concentration of such metals in the cereal crops occurs independently of each other. For instance, in the case of TC/TF the analysis shows that the metal levels in the plant transferred from the soil is independent of the metals translocated from the roots to the soil. Similarly, the metal levels in the aerial plants (leaf and stem) was independent of the metal levels in the soil-root phase with respect to routes of contamination (PUF/TF and PUF//TC).

Correlation between TC/TF was negative for Cu and Pb at SU 1; Cd at SU 2 and for Cd, Cr, Cu and significant difference for Pb at SU 2 (Table 2). The negative correlation remarks that the proximity of SU 1 at a distance of 345.79m to the Kano-Zaria Highway with its high traffic density is independent of the high levels of Pb and Cu particulates in the soil. Copper is used as components of vehicle lubricating oils. It is also used in the manufacture of some components of vehicle engines (Abubakar et al., 2004). Pb is added to fuel as an anti-knocking component for smooth running of the car engine. Similarly, the inverse relationship for Cd at SU 2 reveals a far-distance transport or dispersal of Cd at SU 2 at a distance of 1934.61m from the Highway resulting to lower Cd levels in the soil (Table 2).

A higher inverse correlation and significant value for Cu at SU 3 and high value for Cr (Table 2) shows the influence of traffic density and distance in the TC/TF values, since Cu and Cr are components of vehicular parts. The closer the sampling site to the highway- a direct source of pollution, the higher the deposition, absorption and assimilation of metals from the aerial plant parts to the soil resulting to subsequent translocation from roots to stems. In contrast, a lower value for Cd and Pb levels in Zea mays L. was influenced by meteorological factors like wind (Piron-Frenet et al.,1994), mobile nature of the particulates (Mutch, 1996) resulting to wider dispersion. The dominant wind direction and speed is also due to the presence of the Tiga dam around the site.

Cd and Pb had a low inverse correlation for TC/TF while Cr and Cu had a lower inverse correlation all at SU 4 (Table 2), reflects the influence of distance, for instance the farther the sampling site from the Highway, the lower the value and vice-versa. Zea mays everta L. is the farthest sampling site from the Highway at a distance of 2184.61m.

The negative correlation between PUF/TF was observed at SU 2 for Cd (-0.5926) (Table 2) shows that Cd levels in Pavon-76 is derived from the aerial plant parts and translocated from the soil through the root to the stem. However, the influence of distance is non-evident in this case. This could be related to the species' (Siettecerros) ability to accumulate Cd. The physical and chemical parameters of the soils obtained from the two experimental sampling sites and two control sampling sites in the study area are shown in Table 3.

Table 3: Physicochemical Parameters of Soils from Doruwa Salau at close proximity to the Kano- Zaria road and from the Irrigation Research Station before sowing

					pH				
Site	**% Sand**	**% Silt**	**% Clay**	**Textural Class**	**H20 1:1**	**HCL 1:1**	**% OC**	**% OM**	**CEC**
SU 1	62. 9	15. 2	21. 9	Sandy Clay loam	6. 41	5. 77	0. 88	1. 50	7. 25
SU 2	75. 5	12. 4	12. 1	Sandy loam	5. 48	4. 66	0. 65	1. 12	5. 9
SU 3	71.6	13.5	14. 9	Sandy loam	5.75	4. 86	1. 82	1. 05	6. 3
SU 4	60. 5	17. 2	22. 3	Sandy clay loam	6. 21	5. 40	0. 78	1. 36	8. 01

KEY
SU 1 = Wheat (Pavon-76) on DoruwaSalau at close proximity to the Kano-Zaria road
SU 2 = Wheat (Siettecerros) at the Control Site (Irrigation Research Station-IRS), Kadawa
SU 3 = Yellow Maize on DoruwaSalau at close proximity to the Kano –Zaria road
SU 4 = Popcorn at the Control Site (Irrigation Research Station-IRS), Kadawa

Soil factors like pH, particle sizes, textural class, organic matter, CEC, cultivars, climatic changes and water used for irrigation in the study area influenced the proportion of soil metals (Chan and Hale, 2004; Anongo et al., 2015). The mobility and availability of heavy metals in soil are generally low, especially when soil is high in pH, clay and organic matter (Jung & Thornton, 1996; Rosselli et al., 2003) as well as the growth stages (Liu et al.,2005; Hatamzadeh et al.,2012; Anongo et al., 2015). pH values in this study ranged from 4.66 – 6.41 indicating slightly acidic soils (Table 3). The optimum pH range for most plants is between 5.5 and 7.0; however, many plants have adapted to thrive at pH values outside their range. The pH and textural class of the soils probably increased the levels of Cr, Cu and Zn in these cultivars. Texture plays an important role in heavy metal behaviours like heavy metal mobility, bioavailability and toxicity in the soils and plants (Maclean et al., 1987; Henning et al., 2001). In this study, the textural class with moderate pore spaces contributed to retaining the dissolved forms of the metals in the soils. However, the slightly acidic pH values obtained in this study caused the increased immobility of metals in the soils, thus explaining the positive significant relationship of Cr and Zn in Pavon-76 on sandy clay loam, Cu in Sietteceros on sandy loam soils, Cr in Zea mays L., and Zn in Zea mays L. on sandy loam and Zea mays everta L. on sandy clay loam soils among the risk assessment factors. Furthermore, the organic matter content (Table 3) could have bounded the metals in non-leachable forms thereby reducing their mobility (Amoo et al., 2004; Anongo et al., 2015). The study area which is devoid of commercial, industrial and residential activities except for the presence of a major highway suggests that, it might have attained or reached a state of equilibrium where no further change takes place.

The total amount of heavy metals is usually not an accurate indication of phytotoxicity. The metals in water soluble and exchangeable fractions would be readily available to higher plant roots and therefore are a better indicator of immediate phytotoxicicty (Li et al., 2007). Soil bioavailability.

CONCLUSION

The positive significant relationship between PUF/TC and PUF/TF for Cr and Zn reveals atmospheric inputs and special ability of Pavon-76, siettecerros and popcorn to accumulate metals have phytoextractor potentials for bioremediation approach to reclaim lands polluted with metals. However, non-edible cultivars of these crops should be developed to study their hyper-accumulation and phytoextraction potentials for certain metals.

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APPENDIX

Appendix A: Transfer Coefficient (TC) of the Pavon-76 and Yellow Maize at the Six growth stages at Doruwa Salau closest to the Kano-Zaria road (Experimental Site)

Growth stages, Species,	Trace Metal (mg/kg)				
Sites	Cd	Cr	Cu	Pb	Zn
A1	0. 6729	0. 0407	0. 1495	3. 2553	2. 0011
A3	0. 2999	0. 0200	0. 0658	1. 6330	0. 5504
B1	0. 4265	0. 0305	0. 1632	6. 3222	0. 1372
B3	0. 2086	0. 0061	0. 0815	3. 6414	0. 4586
C1	0. 3940	0. 0330	0. 1946	1. 0133	0. 8045
C3	0. 4172	0. 0297	0. 2038	0. 5216	1. 1315
D1	0. 3225	0. 0294	0. 1634	2. 6799	0. 1395
D3	0. 4062	0. 0216	0. 0541	1. 3347	0. 0741
E1	0. 4860	0. 0193	0. 1796	2. 0449	0. 6421
E3	0. 6960	0. 0328	0. 3002	2. 5523	0. 8053
F1	0. 7618	0. 0272	0. 1526	1. 2765	0. 1138
F3	0. 8267	0. 0451	0. 2210	3. 9682	0. 1088

SOURCE: PhD THESIS 2015

KEY
A = 15 days (germination stage) E = 75 days (flowering stage) 1 = Pavon-76 at Doruwa Salau,
B = 30 days (tillering stage) F = 90 days (ripening stage) 3 = Yellow Maize at Doruwa Salau,
C = 45 days (shooting stage) D = 60 days (heading stage)

Appendix B: Transfer Coefficient (TC) of Siettecerros and Popcorn at the Six growth stages at the Irrigation Research Station (IRS) (Control site)

Growth stages, Species, Sites	**Trace Metal (mg/kg)**				
	Cd	**Cr**	**Cu**	**Pb**	**Zn**
A2	0. 1382	0. 0137	0. 1265	1. 5383	0. 5449
A4	0. 8062	0. 0370	0. 0588	6. 3751	3. 3876
B2	0. 5683	0. 0259	0. 1359	3. 9784	0. 0603
B4	1. 1942	0. 0607	0. 3545	4. 8655	0. 2666
C2	0. 4005	0. 0223	0. 1688	2. 2816	0. 4931
C4	1. 0901	0. 0421	0. 2092	2. 7253	1. 6746
D2	1. 1137	0. 0607	0. 3051	3. 7462	0. 4043
D4	0. 6440	0. 0348	0. 3001	1. 6443	0. 2240
E2	0. 8394	0. 0302	0. 2338	2. 0983	0. 7811
E4	0. 3828	0. 0299	0. 0777	0. 5615	1. 3516
F2	0. 3110	0. 0335	0. 1389	2. 1568	0. 1080
F4	0. 4678	0. 0536	0. 1321	2. 4951	0. 1634

SOURCE: PhD THESIS 2015

KEY
A = 15 days (germination stage) E = 75 days (flowering stage) 2 = Siettecerros at the IRS
B = 30 days (tillering stage) F = 90 days (ripening stage) 4 = Popcorn at the IRS
C = 45 days (shooting stage) D = 60 days (heading stage)

Appendix C: The Plant Uptake factor (PUF) and translocation factor (TF) of the Cereal Crops with respect to the six Growth Stages at Doruwa Salau (Experimental Site – S1).

Growth Stages, Sites, Crops	**Cd**		**Cr**		**Cu**		**Pb**		**Zn**	
	PUF	**TF**	**PUF**	**TF**	**PUF**	**TF**	**PUF**	**TF**	**PUF**	**TF**
A1	2. 357	1. 8	0. 213	6. 535	6. 098	8. 796	400	0. 625	2. 616	0. 990
A3	2. 46	2	0. 127	0. 944	0. 525	1. 214	5. 25	0. 285	0. 716	1. 377
B1	2. 545	2	0. 091	0. 583	4. 741	1. 087	45	1. 166	0. 127	0. 370
B3	0. 666	0. 4	0. 047	6	2. 518	1. 360	1300	0. 774	0. 401	0. 847
C1	1. 384	1	0. 134	1. 053	2. 232	0. 838	3. 5	0. 363	1. 196	1. 642
C3	1. 375	0. 8	0. 119	1. 035	7. 403	0. 849	3	0. 75	1. 320	0. 715
D1	1. 538	1. 333	0. 138	0. 933	5. 935	0. 864	23	3. 5	0. 180	1. 248
D3	5. 5	2	0. 148	0. 506	1. 887	1. 591	5. 375	10.333	0. 091	1. 121
E1	3. 636	1. 667	0. 139	1. 005	6. 725	1. 204	6. 125	0. 75	1. 010	1. 183
E3	1. 714	0. 416	0. 142	1. 049	49. 6	0. 779	9	1. 5	1. 685	2. 537
F1	3. 058	1. 272	0. 167	0. 823	0. 893	1. 282	5. 75	2	0. 176	1. 116
F3	1. 8	1. 142	0. 219	0. 606	2. 276	0. 987	720	1. 166	0. 119	0. 669

SOURCE: PhD THESIS 2015

Underlined numbers = soil Pb was not detected, PUF not computed
Bolded numbers = Highest and lowest value

KEY
A = 15 days (germination stage) E = 75 days (flowering stage) 1 = Pavon-76 at Doruwa Salau,
B = 30 days (tillering stage) F = 90 days (ripening stage) 3 = Yellow Maize at Doruwa Salau,
C = 45 days (shooting stage) D = 60 days (heading stage)

Apendix D: The Plant Uptake factor (PUF) and translocation factor (TF) of the Cereal Crops with respect to the six Growth Stages at the Irrigation Research Station IRS (Control Site – S2)

Growth Stages, Sites, Crops	**Cd**		**Cr**		**Cu**		**Pb**		**Zn**	
	PUF	**TF**	**PUF**	**TF**	**PUF**	**TF**	**PUF**	**TF**	**PUF**	**TF**
A2	1. 307	1. 666	0. 126	0. 955	1. 888	0. 750	880	1. 45	0. 524	0. 715
A4	3. 1	1.333	0. 134	2. 476	2. 585	0. 519	900	0. 95	4. 748	2. 600
B2	1. 692	2. 428	0. 123	0. 811	0. 643	0. 617	1780	5. 333	0. 044	0. 067
B4	3. 230	1. 5	0. 160	1. 246	9. 091	0. 305	620	0. 625	0. 343	1. 042
C2	2	0. 571	0. 109	1. 058	3. 982	0. 685	25. 5	7. 666	0. 690	3. 272
C4	2. 285	0. 33	0. 121	0. 940	3. 958	1. 567	560	1. 714	2. 548	0. 914
D2	2. 285	0. 833	0. 130	0. 894	1. 555	0. 750	660	5	1. 428	2. 636
D4	2	0. 75	0. 193	0. 858	0. 826	0. 336	400	1. 5	0. 227	0. 446
E2	3. 636	1	0. 136	0. 943	7. 606	2. 557	16	2	0. 849	0. 587
E4	1. 375	2	0. 136	1. 020	0. 336	0. 115	220	60	1. 959	3. 725
F2	1. 263	2. 666	0. 153	1. 108	3. 189	0. 798	880	2. 5	0. 148	0. 380
F4	2	2. 5	0. 322	1. 051	1. 505	1. 350	720	1. 666	0. 187	1. 789

SOURCE: PhD THESIS 2015

Underlined numbers = soil Pb was not detected, PUF not computed
Bolded numbers = Highest and lowest value

KEY
A = 15 days (germination stage)
B = 30 days (tillering stage)
C = 45 days (shooting stage)
D = 60 days (heading stage)
E = 75 days (flowering stage)
F = 90 days (ripening stage)
2 = Siettecerros at the IRS,
4 = Popcorn at the IRS