

Original Research Article

Determination of Some Heavy Metals Concentration in Fadama Soils of Ajiwa Irrigation Site, Katsina State

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ABSTRACT: The presence of heavy metals in the soil is of great ecological significance due to their toxicity at certain level of concentration. This study determined the level of some heavy metal contents in agricultural soils of Ajiwa Fadama using both qualitative and quantitative methods of analysis. The soil samples were collected at the depth of 10-15cm from four different locations (i.e. north, east, south and west) of the area. The samples were analyzed for the presence and level of Lead, Zinc, Chromium, Iron and Manganese using Atomic Absorption Spectrometry (AAS) and qualitatively. The results of the AAS analysis revealed total mean concentration of $0.673 \pm 0.4065\text{mgL}^{-1}$, $0.871 \pm 0.271\text{mgL}^{-1}$, $0.805 \pm 5.049\text{mgL}^{-1}$, and $0.882 \pm 0.27175\text{mgL}^{-1}$, $0.814 \pm 0.33725\text{mgL}^{-1}$ for Chromium, Manganese, Lead, Zinc and Iron respectively. These results indicate clearly that the Fadama soils are significantly polluted by heavy metals due to probably the presence of refuse dumps sited in the area and irrigation practices; these can be a threat to the environment and the living things at large, as most of the metals studied are above the literature value except for Zinc and Iron. Recommendations on the need for clean water for irrigation and regular monitoring of the soil to reduce toxicity from the heavy metal were suggested.

Keywords: Fadama, heavy metals, soils, waste water

INTRODUCTION

Heavy metals are elements with metallic properties and an atomic mass greater than 20. The most common contaminants of heavy metal are Lead (Pb), Chromium (Cr), Silver (Hg), Copper (Cu), Zinc (Zn), Manganese (Mn) and Iron (Fe). Heavy metal contamination to soil and the environment has been accelerated in modern society due to industrialization, rapidly expanded world population, and intensified agriculture. Accumulation of heavy metals often results in soil/water degradation and ecosystem malfunction. Moreover, heavy metals enter food chains from polluted soil, water and air, and consequently cause food contamination, thus posing a threat to human and animal health (Singh and Steimens,

2004). Heavy metals uptake in agricultural soils is of increasing concern due to food safety issues and potential health risks, as well as detrimental effects on soil ecosystems. Sources of these elements in soils mainly include natural occurrences derived from parent materials, volcanic eruptions, marine aerosols, forest fires, and human activities (Maliwal, 2014). The anthropogenic sources of heavy metals include traffic emissions (vehicle exhaust particles, tire wear particles, weathered street surface particles, brake lining wear particles), industrial emissions (power plants, coal combustion, metallurgical industry, auto repair shops, chemical plants, etc.), domestic emissions, and weathering

of building and pavement surfaces (Barry et al, 2005). Heavy metal pollution of agricultural soil can result not only in decreased crop output and quality and hurt human health through the food chain, but also further deterioration of air and water environmental quality (Maliwal, 2014). Studies of heavy metal uptake by plants have often revealed their accumulation at a level toxic to human health (Asok et al., 2014). Generally, uptake is increased in plants that are grown in areas with increased soil contamination.

Recently pollution of general environment has increasingly gathered a global interest. In this respect, contamination of agricultural soils with heavy metals has always been considered a critical challenge in scientific community. Heavy metals are generally supposed to be present at small level in agricultural soils due to their accumulative behavior and toxicity; however, they have a potential hazardous effect not only on crops but on human health (Kiekens, 2003).

Chromium (Cr) is a naturally occurring element present in the earth's crust, with oxidation states (or valence states) ranging from chromium (II) to chromium (VI). Elemental Chromium [Cr] does not occur naturally. Chromium compounds are stable in the trivalent [Cr (III)] form and occur in nature in this state in ores, such as Ferro chromite. The hexavalent [Cr (VI)] form is the second-most stable state (Keller et al., 2011). Chromium enters into various environmental matrices (air, water, and soil) from a wide variety of natural and anthropogenic sources with the largest release occurring from industrial establishments. Chromium often accumulates in aquatic life, adding to the danger of eating fish that may have been exposed to high levels of the metals (Berti and Jacobs, 2006).

Lead is a naturally occurring bluish-gray metal present in small amounts in the earth's crust. Although lead occurs naturally in the environment, anthropogenic activities such as fossil fuels burning, mining, and manufacturing contribute to the release of high concentrations. High levels of exposure to lead may cause problem in the synthesis of hemoglobin, acute and chronic damage to the nervous system and reproductive system (AECLP, 2009).

Zinc occurs naturally in the soil about 70g in crushed rock. Zinc is added during industrial activities such as mining coal and waste combustion. Many foodstuffs contain concentration of zinc, drinking water also contain certain amount of zinc. Excess Zinc is strongly toxic and can cause rapid death (Galardo-Lara, 2009).

Manganese is a chemical, designated by the symbol Mn. It has the atomic number 25 density 7.43gcm^{-3} it is found free as a free element in nature (often in combination with iron), and in many minerals. Manganese is pin risk gray metal that resembles irons, it is hard and very brittle, difficult to fuse, but easy to oxidize. Manganese reacts with water (its rust like iron)

and dissolves in dilute acids. Highly toxic concentration of manganese in soil can cause swelling of cell walls, with weathering and brown spots on leaves (Udom et al, 2014).

Iron is a chemical element with a symbol Fe, silvery white, lustrous, malleable, ductile, magnetic and metallic. It occurs abundantly in combined forms, notably as hematite, limonite, magnetite and taconite. It is used in alloy in a wide range of structural materials. Steel is the best known alloy of Iron, and some of the forms that Iron takes include, Pig Iron, Cast Iron, Carbon steel, Wrought Iron, Iron oxides. Iron ingestion accounts foremost of its effect, because it is absorbed rapidly in the gastrointestinal tracts. The corrosive nature of Iron seems to further increase the absorption. Target organs are the liver, cardiovascular system and kidney. Chronic inhalation of excessive concentration of Iron may enhance the risk of lung cancer (Sparks, 2005).

"Fadama" is a word in Hausa language which means, seasonally floodable or floodable flood plan along major savannah rivers and depressions on the adjacent low terraces. The need for improvement in Fadama lead to development of small irrigation pumps, wash bores, and shadow tube wells for Small Scale Irrigated Farming System (SSIFS). This has existed in the Nigerian Sudano-Sahelian region before introducing the Large Scale Irrigated Farming System (LSIFS) to Nigeria. These two systems have been introduced by the government, while farmers only diverted water from the channels to their individual farms (Mashi et al., 2015).

MATERIALS AND METHODS

Sample collection and pre-treatment

The soil samples were collected at a depth of 10-15cm from four different locations in the area (North, East South and West). They were oven-dried at 105°C in order to obtain constant weights. The dried samples were then crushed and sieved through a 2 mm sieve to remove gravel fractions and stored in polythene bags prior to digestion

Sample digestion

One gram sub-samples was taken into crucibles to which few drops of distilled water were added to prevent sputtering. DTPA (diethylenediaminepent acetic acid) extraction method (Hanlon et al, 2009) was then used to extract the metals from the samples because it has widely been used as an extractant to indicate the bioavailability of numerous heavy metals in soils. The concentrations of various heavy metals in the extractants were determined by atomic absorption spectrometry.

Statistical analysis

Mean and standard deviations values for every metal were computed for each of the four selected areas from the obtained data. Student's t-test was then used to test for significant difference in mean values of each metal between the soils of the Fadama areas under investigation.

RESULTS

Table 1 give the result of qualitative analyses of the soil samples where it indicates the presence of the metals selected. While (Tables 1, 2.1-2.5) give respectively the concentrations in mgL^{-1} , mean and standard deviations values for the various heavy metals for each of the four selected locations of the Fadama. It is clear from the five tables that the metals were concentrated in higher amounts in sample D (North) which was an indication of downward movement of the metals in profile of the soils. This downward movement was a reflection of the ease with which water penetrated the depth in the extensive network of large cracks characterizing alluvial Fadama soils in northern Nigeria. A close look at the five tables indicated that in the four soil samples, Zn was generally the most abundant, followed by Mn, then Fe, Pb and Cr was the least abundant metal in the soil samples. These indicate that the Fadama soil was polluted as a result of domestic activities and agricultural practices.

DISCUSSION

The result of the qualitative test in (Table 1) showed the presence of the metal ions to be identified from the soil samples. The metal ions were identified by their characteristic colour in which Cr^{3+} is yellow, Fe^{2+} is deep blue, Fe^{3+} is blood red, Pb^{2+} is also yellowish, Mn^{2+} is creamy and Zn^{2+} is white. Table 2 showed the results of AAS analysis for the identified metal ions to determine their concentrations in the soil samples. The concentration of chromium ions shown in (Table 2a) was found to be within the ranges of $0.028\text{-}0.428\text{mgL}^{-1}$, $0.048\text{-}0.448\text{mgL}^{-1}$, $1.025\text{-}0.226\text{mgL}^{-1}$ and $1.994\text{-}1.194\text{mgL}^{-1}$ for east(A) west(B), south(C) and north(D) soil samples respectively. Sample D was found to contain maximum concentration of chromium ions from the result.

The Concentration of manganese shown in (Table 2b) was found to be within the range of $0.073\text{-}0.373\text{mgL}^{-1}$, $0.476\text{-}0.776\text{mgL}^{-1}$, $0.989\text{-}1.289\text{mgL}^{-1}$ and $2.014\text{-}1.11\text{mgL}^{-1}$ for sample A, B, C and D respectively. Here also sample D contain maximum concentration of Manganese ion from the result. Table 2c showed the concentration of Lead ions in which it ranges between $0.101\text{-}0.501\text{mgL}^{-1}$, $0.503\text{-}0.903\text{mgL}^{-1}$, $1.040\text{-}0.240\text{mgL}^{-1}$

and $1.979\text{-}1.179\text{mgL}^{-1}$ for soil sample A, B, C and D respectively. Soil sample D has the highest concentration of Lead from the result. The concentration of Zinc ions shown in (Table 2d) ranges between $0.088\text{-}0.388\text{mgL}^{-1}$, $0.533\text{-}0.833\text{mgL}^{-1}$, $0.977\text{-}1.277\text{mgL}^{-1}$ and $2.000\text{-}1.100\text{mgL}^{-1}$ for A, B, C and D respectively. Here also sample D has the highest concentration of the Zinc metal ions. Table 2e showed the concentration of Iron metal ions within the range of $0.081\text{-}0.48\text{mgL}^{-1}$, $0.569\text{-}0.969\text{mgL}^{-1}$, $1.056\text{-}0.256\text{mgL}^{-1}$ and $1.951\text{-}1.151\text{mgL}^{-1}$ for Sample A, B, C and D respectively. These results also indicate highest concentration of Iron metal in sample D.

Table 2f showed the total mean concentrations of all the metal ions analyzed, where it indicates mean values of $0.673\pm 0.4065\text{mgL}^{-1}$, $0.871\pm 0.271\text{mgL}^{-1}$, $0.805\pm 5.049\text{mgL}^{-1}$, $0.88 \pm 0.27175\text{mgL}^{-1}$ and $0.814\pm 0.33725\text{mgL}^{-1}$ for Chromium, Manganese, Lead, Zinc and Iron respectively. In managed agricultural soils, it is generally assumed that heavy metals are immobile (Berty and Jacob, 2006). However, in an agricultural ecosystem, some factors that enhance the mobility of such metals can result in plant uptake or leaching to groundwater. Such factors include texture, pH and competing cat ions in soil solution. Dowdy and Volok, (2004) and Smith (2001) have shown that where waste disposal is made on sandy, acidic, low organic matter soils receiving high rainfall or irrigation water, the movement of heavy metals into lower soil layer tends to be high (Kou et al., 2005), while Maliwal, (2014), noted that heavy metal mobility is most closely associated with metal-organic composition and soil PH. Use of organic manure by the farmers cultivating the soils brings about some improvement in organic carbon contents of the soils.

It is thus expected that the heavy metals studied here exhibit high mobility in the soils. Use of effluents for raising crops is a common practice in semi-urban areas of many developing cities. Accumulation of heavy metals on lands receiving such effluents is however of much scientific significance and health concerns (McBride et al., 2009). Under natural conditions, bioavailable forms of heavy metals in soils of such lands are expected to concentrate in higher amounts in the topsoil because the factors that promote such bioavailability (such as pH and organic matter) are typically concentrated in higher amounts there (Alloway, 2005). With continuous applications of wastewater to excessively drained soils in hot climatic regions, like those of the study area, downward movement of the metals in a soil profile could be expected (Sparks, 2005). As this downward movement of the metals continues, it is possible that ground water sources could be polluted as well clay is an important colloid promoting retention of metallic elements in soils, it is expected that such an argali horizon can promote retention of the heavy metals migrating to the lower soil layers in the study area from where they can be

Table 1: Result of Qualitative test of the metal ions.

S/N	TEST	OBSERVATION	INFERENCE
1.	To 2cm ³ of the digested sample in a test-tube Conc. HNO ₃ was added and warmed. Few drops of Ammonium solution were also added followed by 1cm ³ of H ₂ O ₂ to the precipitate(ppt) and boiled.	Yellow ppt was obtained, soluble in excess NaOH..	Chromium ions (Cr ³⁺)
2.	To 2cm ³ of the digested sample in a test-tube 2 drops of Potassium Hexacyanoferrate(iii) were added	Deep blue ppt was obtained, soluble in excess NaOH	Iron(ii)ions (Fe ²⁺) present.
3.	Two drops of Potassium thiocyanate solution was added to 2cm ³ of the digested sample followed by excess NaOH..	Blood-red ppt was obtained, soluble in excess NaOH.	Iron(ii) (Fe ³⁺) present.
4.	Two drops of ammonium Chloride were added to the digested sample followed by dil. HCl and warmed.	Creamy ppt was obtained in excess HCl.	Manganese ions(Mn ²⁺) present.
5.	Potassium iodide was added to 2cm ³ of the digested sample followed by NaOH in excess.	Yellow ppt was obtained, soluble in excess NaOH	Lead(ii)ions (Pb ²⁺) present
6.	Ammonium Hydroxide solution was added to 2cm ³ of the digested sample in excess.	White gelatinous ppt was obtained, soluble in excess NH ₄ OH solution.	Zn ions(Zn ²⁺) present.

Table 2a: Concentration of Chromium in mgL⁻¹.

S/N	Soil Samples	1 st	2 nd	3 rd	Mean	± St.Dev.
1.	A(East)	0.028	0.228	0.428	0.228	0.015
2.	B(west)	0.048	0.248	0.448	0.248	0.121
3.	C(South)	1.025	0.625	0.226	0.625	0.387
4.	D(North)	1.994	1.594	1.194	1.594	0.618
					0.673	0.4065

Table 2b: Concentration of Manganese in mgL⁻¹.

S/N	Soil Samples	1 st	2 nd	3 rd	Mean	± St.Dev.
	A(East)	0.073	0.173	0.373	0.206	0.074
2.	B(west)	0.476	0.376	0.776	0.609	0.127
3.	C(South)	0.989	1.089	1.289	1.122	0.172
4.	D(North)	2.014	1.514	1.114	1.547	0.711
					0.871	0.271

lost to underground water sources in solution. This can consequently serve as an important source of groundwater pollution in the area. Compared with the other heavy metals studied, Zn and Fe have the least toxicity effects and are in fact metals essentially required in minute amounts. Likewise, the mean concentrations of the other metals (Cr, Mn and Pb) in the soil samples analyzed are on a high side for environmental safety standards. In fact, there are no known lower limits of Pb for tolerance by human body systems.

The high accumulation of all the metals analyzed in the D (north) section of the Fadama soil can be attributed to

high use of wastewater in irrigating the soil. In the area, this clearly raised the level of the metals.

Adsorption, defined as the accumulation of a substance or material at an interface between the solid surface and the bathing solution, is identified as the most important chemical process controlling the behavior and bioavailability of metals ions in soils (Yu et al., 2007). Surface charge, pH and the concentration of ions, as well as of its accompanying anions, can affect electrostatic adsorption of metals, while organic matter, Fe and Anhydrous oxides, and clay content are recognized as the most significant soil properties influencing adsorption

Table 2c: Concentration of lead in mgL⁻¹.

S/N	Soil Samples	1 st	2 nd	3 rd	Mean	± St.Dev.
1.	A(East)	0.101	0.301	0.501	0.301	0.134
2.	B(west)	0.503	0.703	0.903	0.703	0.205
3.	C(South)	1.040	0.640	0.240	0.640	0.391
4.	D(North)	1.979	1.579	1.179	1.579	0.616
					0.805	5.049

Table 2d: Concentration of zinc in mgL⁻¹.

S/N	Soil Samples	1 st	2 nd	3 rd	Mean	± St.Dev.
1.	A(East)	0.088	0.188	0.388	0.221	0.076
2.	B(west)	0.533	0.633	0.833	0.666	0.132
3.	C(South)	0.977	1.077	1.277	1.110	0.171
4.	D(North)	2.000	1.500	1.100	1.533	0.708
					0.8825	0.27175

Table 2e: Concentration of iron in mgL⁻¹.

S/N	Soil Samples	1 st	2 nd	3 rd	Mean	± St.Dev.
1.	A(East)	0.081	0.281	0.481	0.281	0.129
2.	B(west)	0.569	0.769	0.969	0.769	0.214
3.	C(South)	1.056	0.656	0.256	0.656	0.396
4.	D(North)	1.951	1.551	1.151	1.551	0.610
					0.814	0.33725

Table 2f: Total mean concentration of chromium, manganese, lead, zinc and iron in mgL⁻¹.

	Cr	Mn	Pb	Zn	Fe
Mean	0.673	0.871	0.805	0.8825	0.814
±St.Dev.	0.4065	0.271	5.049	0.27175	0.33725
Literature value	0.126	0.82	0.769	1.04	1.640

reactions (Bolan and Duraisamy, 2013). The presence of competitive cat ions, which also varies with time, can affect metal adsorption in soils. For instance, Ca²⁺ competes effectively with cationic heavy metals for adsorption sites, and this competition seems to be greater for Zn, Cu and Pb (Kiekens, 2003). This occurs because Zn is basically retained in the soil by exchange reactions, while Cu and Pb form inner-sphere complexes with organic matter and Fe, and Mn oxides. The solubility of Zn, Cu, and Pb is higher in alkaline pH as a result of formation of stable soluble organo-mineral complexes. On the other hand, if pH ranges between 4 and 6, the solubility of these metals would be lower because of formation of insoluble sulfides or insoluble organo-mineral complexes (Kiekens, 2003).

Conclusion

The Fadama soils of Ajiwa in Batagarawa local government area near Katsina City are significantly

polluted by the wastewater high in contents of several heavy metals. In fact, the levels of all the other three metals studied have significantly been elevated in the Fadama soils. this should be of great concern because most of the studied metals have no known threshold levels for human intakes.

RECOMMENDATIONS

To mitigate this problem, it is recommended that;

1. Efforts should be made to provide alternative, cleaner water for Fadama irrigation in the area.
2. Farmers should be encouraged to use clean water for the irrigation to reduce the accumulation of the heavy metals in the soil.
3. Legislations against pollution of water in the area should be made stricter.
4. Further researches are required in the area to ascertain the extent of the heavy metals toxicity in the soil.

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