International Journal of Environmental Monitoring and Analysis
2014; 2(2): 106-111
Published online April 30, 2014 (http://www.sciencepublishinggroup.com/j/ijema)
doi: 10.11648/j.ijema.20140202.17

Heavy metal concentration levels in soil at Lake Geriyo irrigation site, Yola, Adamawa state, North Eastern Nigeria

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To cite this article:
Hong, Aliyu Haliru, Law, Puong Ling, Selaman, Onni Suhaiza. Heavy Metal Concentration Levels in Soil at Lake Geriyo Irrigation Site, Yola, Adamawa State, North Eastern Nigeria. *International Journal of Environmental Monitoring and Analysis*. Vol. 2, No. 2, 2014, pp. 106-111. doi: 10.11648/j.ijema.20140202.17

Abstract: The study assessed the physicochemical parameters and mean concentration levels of heavy metals in soil at two selected wastewater receiving sites and control site of Lake Geriyo irrigation project in order to determine the extent of heavy metal pollution due to wastewater irrigation using standard methods. The pH values at the River Benue, Shinko and control site soils were slightly acidic to neutral with mean value of 6.85, 5.75 and 7.0 respectively. Mean electrical conductivity values were 1.08µs/cm, 1.54µs/cm and 1.95µs/cm and organic matter levels are 0.75%, 2.11% and 3.5%. The textural classification of the soils revealed that the soils are predominantly sandy in nature with 56.4%, 55.6% and 50.4% sand, 20%, 16.0% and19% are clay, while 24.0%, 28.4% and 30.0% are silt. The mean concentrations of heavy metals (Fe, Zn, Mn, Cu, Cd, Cr, Pb and Ni) recorded in River Benue site soil are 86.89mg/kg, 74.38mg/kg,12.76mg/kg, 15.08mg/kg, 9.83mg/kg, 11.0mg/kg, 7.17mg/kg and 18.73mg/kg. Shinko site recorded concentration levels of 292.7mg/kg, 309.2mg/kg, 130.9mg/kg, 253.8mg/kg, 199.2mg/kg, 158.7mg/kg and 74.43mg/kg respectively, while the control site soil had concentration levels of Fe 58.48mg/kg, Zn 39.44mg/kg, Mn 7.13mg/kg, Cu 9.40mg/kg, Cd 7.62mg/kg, Cr 9.82mg/kg, Pb 6.28mg/kg and Ni 17.62mg/kg. The result showed that the concentrations of heavy metals at River Benue and Shinko site soils are more polluted than the control site soil with Shinko site soil exhibiting high levels of heavy metals concentration. Comparative analysis of this study and International threshold values of heavy metals concentration levels in soil revealed that most of the parameters at Shinko site soil are elevated above the EU, USA and UK Standards. Future study is hereby recommended to focus on the impact of heavy metal concentration on irrigated vegetables as some may find their way into the food chain and cause public health hazards to consumers.

Keyword: Wastewater, Heavy Metal, Pollution, Physicochemical, Irrigation

1. Introduction

Soil can be defined as that unconsolidated minerals and organic material found on the immediate earth surface that serves as a natural medium for plants growth and other developmental activities (Brady and Weil, 2008). Soil also act as a key component of the natural ecosystems and environmental sustainability largely depends on a sustainable soil ecosystem and any alteration as a result of either pollution or contamination ultimately alters the ecosystems and agricultural activities are also greatly affected (Hankard et al, 2004, and Ayeni et al, 2010).

Due to rapid increase in human population, industrialization, urbanization over the years, human life styles and activities have tremendously affected the environment greatly. One of the most significant impacts is heavy metal pollution of farmland as it serves as an intimate linkage to human food chain (Niu et al, 2013). The accumulation of metals in agricultural farmland does not only decrease the productivity and quality of crops grown, but it also greatly threatens the safety of ecosystem and human health through adverse effect.

Handling and disposal of liquid waste containing heavy metals is one of the major challenge and threat to environmental wholesomeness in Nigeria where the average household waste generation is put at 0.55 – 0.58kg per capita (SWAR, 2004). The manufacture and distribution of products such as soap, cream, batteries, perfumes, deodorant, metal scrap, textiles, plastics, scrap tyres and garbage as well as disposables have resulted to generation of huge volume of waste. The composition of this waste is an important source of environmental pollution and will contribute to heavy metal load in soils.

The consequences of soil contamination/pollution with heavy metals could be through direct ingestion of contaminated soil including soil particulate, dermal absorption, ingestion of groundwater contaminated by harzadous heavy metals eluted from contaminated soil, inhalation of harzadous substances emitted from contaminated soil to atmosphere, discharge of soil containing harzadous substances to municipal water ways, accumulation in aquatic ecology, ingestion by human beings, accumulation of hazardous substances in crops and livestock raised on contaminated land are some of the partway through which health impact of contaminated soil could affect public health.

At present in Zamfara State in the northwestern part of Nigeria a reported case of lead poisoning from lead contaminated soil mining was recorded in which over 2000 children and pregnant women were affected (Nigerian Daily Trust, 2013). Lead that contaminates the environment is largely deposited by dust into soil and water and is taken up by or exists on the surfaces of plants which are grazed by livestock, cattle, sheep, and horses which are good indicators of pollution on vegetation (Debackere, 1983). Bala et al, 2013 reported high concentration of lead in liver, kidney and muscle of slaughtered cattle at Jos Central Abattoir and attributed it to grazing on plant and feeds from lead contaminated soil. Heavy metal accumulation in soil is of increasing concern because of the potential of risk of its uptake and transfer into food chain. Therefore soil as an environmental resource should be protected from further degradation and contamination from pollutants especially heavy metals so as to produce healthy food for the worlds increasing population. The objective of this work, therefore, was to determine the concentration of heavy metals in soil at Lake Geriyo irrigation site that has been on wastewater effluent irrigation during the dry season for more than ten years.

2. Materials and Methods

2.1. Study Area

Adamawa State is located in the northeastern part of Nigeria with a population of 3,737,223 people and land mass of 36,917km^2. Yola (Jimeta) the Adamawa State capital is located between Longitudes 12° 26' E and Latitude 9° 16' N (http://www.en.wikipedia.org/wiki/jimeta) along the banks of River Benue (Adebayo, 1999). Lake Geriyo lies between Longitude 12° 00' and 12° 28' East of Greenwich and Latitude 9° 16' and 9° 19' North of the equator. It has devoted land area of 1200 hectares for dry season irrigation (Fig 1). The state is in the Sahel region of Nigeria generally Semi arid with low rainfall, low humidity and high temperature. The area experiences two distinct wet and dry seasons, the wet season starts from April to October while the dry season starts from November to April. Mean daily temperature fluctuates with season from 25°C to 45°C and mean annual rainfall received is in the range of (250 – 1000mm). The climate is characterized by high evapotranspiration especially during dry season (Adebayo, 1999). Jimeta/Yola the State capital has an estimated population of 600,000 people (NPC, 2006).

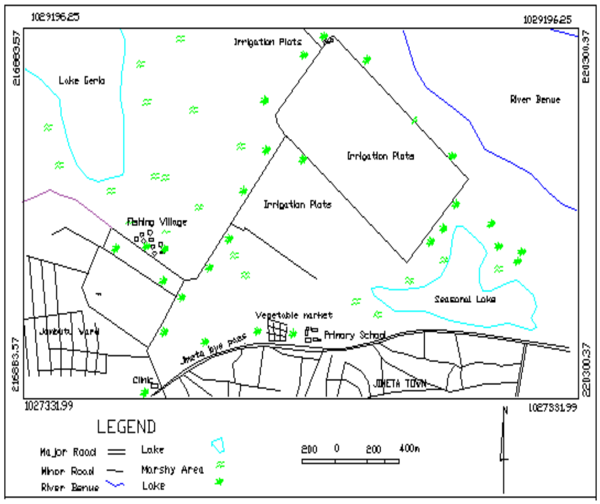

Fig 1. *Lake Geriyo Irrigation Sites.*

2.2. Soil Sampling

A detailed soil reconnaissance survey was conducted where two sites were selected for this research namely: River Benue plot wastewater irrigation site (RBS), Shinko municipal wastewater irrigation site (SHS) and Federal university of Technology Yola research farm soil believed not to be contaminated and uses clean water (tape water) irrigation was selected as control to gauge the difference in the two wastewater receiving sites. A representative composite soil samples was taken from Shinko site, river Benue site and the control site at a depth of 0 - 30cm each using soil sampling spiral auger. The samples were taken in labeled polytene bags to differentiate the sampling points, dried, grounded and sieved through 2mm size sieve and taken to the laboratory for analysis.

2.3. Analytical Procedure

The parameters that were analyzed in the soil samples include, soil particle size distribution, pH, electrical conductivity (EC), organic matter content (OM), trace and heavy metals (Fe, Zn, Mn, Cu, Cd, Cr, Pb and Ni). The soil particle distribution analysis was carried out by adopting the Bouyoucos Hydrometer method where the textural classification was interpreted on the USDA triangle into percentage sand, silt and clay. The analytical method adopted for testing soil pH was the potentiometric method using pH meter (model Jenway 3310) well calibrated using buffers of pH 4.0, 7.0 and 10.0 and the electrode immersed in 1:1 soil/water solution. Conductivity was also measured in 1:1 soil/water extract using Jenway conductivity meter

(4510 model). Soil organic matter was determined by the Walkey - Black procedure (Bai et al., 2010)

2.4. Digestion of Soil Samples

The soil samples initially collected from the two wastewater irrigated site and the tape water sites in triplicate, were oven dried, sieved through 2mm mesh size and stored at room temperature. The soil samples was extracted by taken 2g oven dried soil into a Pyrex beaker, 15ml of aqua regia (hydrochloric/nitric acid) was added and the mixture was allowed to stand for 16 hours at room temperature, and then followed by boiling under reflux for 2 hours at 160°C. The extract was filtered and clarified and make up to the volume with nitric acid.

2.5. Heavy Metal Analysis

In the acid extract, the concentration of trace and heavy metals (Fe, Zn, Mn, Cu, Cd, Cr, Pb and Ni) were determined by using fast sequential Atomic Absorption spectrometer (AA240FSModel) after calibration and selection of the various wavelengths at which all the heavy metal are eliminated and tested. To ensure quality control, blank reagent and standard reference solution of all the trace and heavy metals in soil were included in each sample batch to verify the accuracy and precision of the digestion procedure and subsequent analysis.

2.6. Data Analysis

The recorded physicochemical and heavy metal data were analyzed using SPSS (17.0) statistical software and all measurement were expressed in terms of mean values. Also Microsoft excel software (Microsoft 2003) was used to evaluate graphically.

3. Results and Discussions

Table 1 presents the results of physicochemical properties of soils recorded at River Benue, Shinko and the control site. The pH value recorded at the RBS site ranged from 6.4 – 7.3 with mean of 6.85, while that of SHS site ranged from 5.4 – 6.1 with mean of 5.57. The control site pH ranged from 6.5 – 7.5 with mean of 7.0. The result of pH at the RBS site exhibited slightly acidic to slightly neutral, while at the SHS site the pH value is acidic. The control soil was neutral. The acidic nature of soil at the SHS site could influence the mobility and bioavailability of heavy metals in soil (Jan et al., 2010). Kashem et al, 2006, and Khan et al, 2010 also affirmed and reported high Cd concentration at low pH, while increased bioavailability is also reported at low pH by (Sukreeyapongse et al., 2002). Thus, pH as a key parameter controlling heavy metal transfer behavior in soils, the observed values in this study may have implications on the availability and uptake of metal by plant grown on these soils.

Table 1. *Physicochemical Properties of Soil at River Benue, Shinko and Control Sites.*

Sites	Soil depth (cm)	pH range	mean	EC (µs/cm) range	mean	OM (%) range	mean	Sand (%)	Clay (%)	Silt (%)	Textural Class
RBS	0 - 30	6.4 -7.3	6.85	0.56-1.60	1.08	0.20 – 1.30	0.75	56.4	20.0	24.0	SCL
SHS	0 – 30	5.4 – 6.1	5.75	0.88-2.20	1.54	1.90-2.30	2.11	55.6	16.0	28.4	SCL
Control	0 – 30	6.5 - 7.5	7.0	0.90- 3.0	1.95	3.0 – 4.0	3.5	50.4	19.6	30.0	Loam

RBS = River Benue site, SHS = Shinko site, EC = Electrical conductivity, OM = Organic matter

The electrical conductivity values at RBS site ranged from 0.56 – 1.60µs/cm with mean value of 1.08µs/cm and at SHS site it ranged from 0.88 – 2.20µs/cm and mean of 1.54µs/cm. The control soil had a range of 0.90 – 3.0 µs/cm and mean of 1.95 µs/cm. Higher value of EC were recorded at SHS site and the control site. The values are however lower than the values reported by Oviasogie et al., (2007) for physicochemical properties of soil in a foam manufacturing industry in Nigeria. The low conductivity values recorded in this study imply that there is low level of organic salts in these soils.

The levels of mean percentage organic matter in RBS soil ranged from 0.20 – 1.30% and mean value of 0.75%, while SHS soil organic matter level is in the range of 1.90 – 2.30% and the mean value is 2.11%. The control soil mean percentage organic matter level ranged from 3.0 – 4.0% with mean of 3.5% (Table 1). Higher mean percentage organic matter was recorded in SHS soil and the control soil. Brady and Weil (2008) classified organic matter level of soil into classes: < 0.4% organic matter of soil as very low, 1.0 – 1.5% as moderate organic matter soil and > 2.0% as high organic matter soil. Based on this, all the soils under consideration fell into the class of moderate to high organic matter level soils. The values of the percentage organic matter observed was consistent with those reported in another related study (Osenwata, 2009). Organic matter in soil and sediments plays a key role in influencing the physical, chemical, distribution, mobility and availability of cat ions and anions in the natural soil and water environment (Osakwe, 2013).

The results of particle size distribution and textural classification of soil under study revealed that RBS had 56.4% sand, 20.0% clay, and 24.0% silt (Table 1), the textural class was sandyclayloam (SCL), while SHS soil had 56.6% sand, 16.0% clay, and 28.4% silt, the texture class is also sandyclayloam. The control soil had 50.4% sand, 19.6% clay and 30.0% silt and texture was loam soil. The soil particle size analysis indicated that all the soils are predominantly sandy in nature at 0 – 30cm depth meaning that water can infiltrate faster in these soils owing to much larger sand particles and pore spaces between soil particles, hence frequent application of water and low water retention capacity of this soil is expected under irrigation. Application of wastewater on this soil under irrigation means that crops can easily absorbs heavy metals in this water depending on the wastewater composition.

Table 2. *Heavy metals concentration levels of River Benue and Shinko irrigation sites.*

Heavy metals (mg/kg)	RBS Site		SHS Site		Control Site	
	Range	mean	Range	mean	Range	mean
Fe	71.0 – 109	86.89	56.0 – 506	292.7	40.0 – 88.0	58.48
Zn	61.0 – 88.4	74.38	123.0 426.0	309.2	30 – 56.1	39.44
Mn	9.0 – 18.1	12.78	31.1 – 367.0	130.9	3.0 – 13.0	7.13
Cu	10.0 – 20.2	15.08	135.0 -400	253.8	5.0 – 19.1	9.40
Cd	9.0 – 11.1	9.83	86.0 – 506.2	239.2	4.0 – 10.1	7.62
Cr	10.0 – 13.0	11.0	145.0 290.1	199.2	7.0 – 12.0	9.82
Pb	6.0 – 8.1	7.17	110.2 – 269.0	158.7	4.0 – 8.0	6.28
Ni	17.0 – 20.1	18.73	23.0 -130.1	74.43	15.0 – 20.0	17.62

RBS = River Benue Soil, SHS = Shinko Soil

The results of trace and heavy metals concentration recorded at RBS, SHS sites and the control site is presented in Table 2. The results showed that heavy metal concentrations were generally higher at SHS soil than at RBS and the control soil. Previous studies have indicated that surface soils are better indicators of metallic pollution (Amusan et al, 2005). This is expected since almost all the wastewater from small scale industries, hospitals, abattoir are directly disposed on this soil, the site have some high levels of heavy metal enrichment than the other soils (Table 2).

The mean concentration of Fe ranged from 71.0 – 109 mg/kg and mean of 86.89mg/kg in RBS site, while 56.0 – 506mg/kg and mean of 292.7mg/kg was recorded for SHS site soil. The control site soil had a range of 40 – 88.0mg/kg with mean value of 58.48mg/kg. SHS site soil exhibited significantly higher value of Fe than RBS and the control site soil. Similar levels of Fe have been reported by (Osakwe, 2013). However, abundance of Fe in this soil could be attributed to the presence of some automobile scraps, mechanic workshop wastewater, wears and tears of automobile parts. Excessive levels of Fe in soil used for crop production might result in high levels of Fe in produce which may enter food chain to cause vomiting, nausea, anxiety, tension, brain hemorrhage, metabolic disorder and cardiac arrest (Kaur and Mehra, 2012).

The concentration levels of Zn, Mn and Cu in RBS soil ranged from 61.0 – 88.4mg/kg, 9.0 – 18.1mg/kg, and 10.0 – 20.2mg/kg and mean values of 74.38mg/kg, 12.78mg/kg, and 15.08mg/kg respectively. SHS recorded concentration range of 123.0 – 426.0mg/kg, 31.1 – 367.0mg/kg and135.0 – 400.0mg/kg with mean values of 309.2mg/kg, 130.9mg/kg and 253.8mg/kg. At the control soil concentration of Zn, Mn and Cu ranged from 30 – 56.1mg/kg, 3.0 – 13.0mg/kg and 5.0 – 19.1mg/kg, their observed mean values are 39.44mg/kg, 7.18mg/kg and 9.40mg/kg. The results revealed that the concentrations significantly higher at SHS and RBS soil as compared to the control soil (Fig 1 and 2). The concentrations of Cu and Zn observed in this study are higher than that reported in Osakwe, 2013. Copper in soil could result from metal bearing wears and Babbitt metal bushings. Although Cu is an essential element but at higher concentration in soil as discovered in this study crop could absorb it to phytotoxic level to cause anemia, gastrointestinal disorder and also leads to liver and kidney malfunctioning in critical cases(USEPA, 1999). The presence of Zn also could be due to corrosion of metal parts of automobiles. Excessive concentration of Zn in food may result in health disorder such as diarrhea, vomiting and abdominal pain (Adaipo et al, 2005).

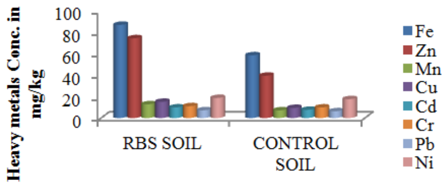

Fig 1. Variation *of Heavy metal Concentration in RBS Soil and Control soil.*

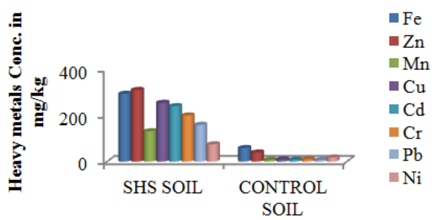

Fig 2. *Variation of Heavy metal Concentration in SHS Soil and Control soil.*

The concentration levels of Cd, Cr, and Pb in RBS soil ranged from 9.0 – 11.1mg/kg, 10.0 – 13.0mg/kg and 6.0 – 8.1mg/kg respectively. Their mean values are 9.83mg/kg, 11.0mg/kg and 7.17mg/kg. In SHS soil, the value range between 86.0 – 506mg/kg, 145.0 – 290.1mg/kg and for Pb 110.2 – 269.0mg/kg was recorded. Their mean values are 239.2mg/kg, 199.2mg/kg and 158.7mg/kg. At the control site soil, the parameters ranged from 4.0 – 10.1mg/kg,7.0 – 12.0mg/kg and 4.0 - 8.0mg/kg. The mean values are 7.62mg/kg, 9.82mg/kg and 6.28mg/kg. The values of Cd, Cr and Pb showed that RBS and SHS soil are highly enriched with the heavy metals as compared to the control soil (Fig 1 and 2). Nickel concentrations in both RBS and SHS soil ranged from17.0 – 20.1mg/kg, 23.0 – 130.1mg/kg with mean of 18.73mg/kg and 74.43mg/kg. The values of Ni at the control site soil range from 15.0 – 20.0mg/kg with mean value of 17.62mg/kg. Generally, higher levels of Cd, Cr and Pb observed in these soils as compared to the control soil revealed an elevated level of heavy metals in agricultural soils. The values of Cd, Cr and Pb are higher than that reported in Osakwe, 2013. This could probably be due to the presence of lead- based, chromium and cadmium discarded batteries which have enriched the soils. The resultant effect of heavy metals enriched into agricultural soil is that crop might absorb them to a higher level that could expose consumers of the crop to health risk. Lead poisoning as reported by Kaur and Mehra, 2012 causes gastrointestinal neuromuscular and nervous system disorder and can also damage liver and kidney, reduce formation of hemoglobin and infertility and defects at birth.

Table 3. *Comparison between International threshold values for heavy metals concentration level in soil regulatory systems (CCME, 2003) and present work*

Heavy metals	EU	USA	Canada	UK	RBS Site	SHS Site
Cd (mg/kg)	3.0	3.0	19.5	1.4	9.83	239.2
Zn	300	200 - 300	1400	200	74.38	309.2
Cr	180	400	1500	6.4	11.0	199.2
Cu	140	80 - 200	170	63	15.08	253.8
Pb	300	300	150	70	7.17	158.7
Ni	75	50 - 110	210	50	18.73	74.43

EU = European Union, USA = United State of America, UK = United Kingdom

Table 3: Presents comparison of heavy metals concentration in soils between the present work and International regulatory systems for threshold values for heavy metals concentration levels in soils.

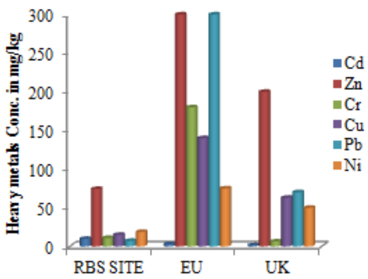

Fig 3. *comparison of Heavy metal Concentration in RBS Site and EU,UK Standards.*

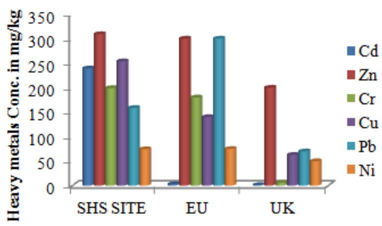

Fig 4. *Comparison of Heavy metals concentration in SHS Site and EU, UK Standards.*

Mean concentration values of Cd recorded at RBS and SHS site soil were 9.83mg/kg and 239.2mg/kg, comparatively, the values are higher than EU, USA and UK standards of 3.0mg/kg and 1.4mg/kg at both sites. Similarly, the concentrations values of Cr, Cu, Pb and Ni recorded at RBS and SHS site soil with values of 11.0mg/kg, 199.2mg/kg, 15.08mg/kg, 253.8mg/kg, 158.7mg/kg and 158.7mg/kg are higher than 6.4mg/kg, 63.0mg/kg, 70.0mg/kg and 50.0mg/kg values specified by UK standard (Fig 3). Generally, the comparison revealed that the concentration of heavy metals at RBS and SHS sites soil was highly elevated above the maximum permissible level for soils standard obtainable from European Union and the United Kingdom (Fig 4). This comparison showed that some degrees of contamination of soil at the two sites are evident which urgently require an intervention measures as long as irrigation of edible crops are grown on these soil.

On the whole, the heavy metals concentrations trends in soil at the RBS and SHS sites are in the order: Fe > Zn >Ni >Cu >Mn >Cr > Cd > Pb and Zn >Fe > Cu > Cd > Cr > Pb > Mn > Ni.

4. Conclusion

The results of physicochemical analysis indicate that the soils were slightly acidic to neutral, EC values imply the presence of considerable level of inorganic salt, while the soil have an appreciable organic matter level to influence the transfer and bioavailability of heavy metals enrichment from wastewater into soil. The concentration levels of some heavy metals in soil are elevated above the control soil and the established international guidelines for heavy metals in soils. SHS site soil is more polluted than RBS soil when compared to the control soil which might be due to industrial and anthropogenic activities close to the study area may be responsible for the observed soil pollution. Future study are hereby recommended to focus on the impact of these heavy metals on irrigated vegetables as some may find their way into food chain and cause public health hazards on consumers.

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