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Full Length Research Paper

Risk assessment on bioaccumulation of potentially toxic elements on soil and edible vegetables *Corchorus olitorius* and *Amaranthus cruentus* grown with water treatment sludge in Chanchaga Minna, Niger state, Nigeria

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ABSTRACT

This study investigate the bioaccumulation of potentially toxic elements build-up in vegetables *Amaranthus cruentus*, and *Corchorus olitorius* grown with water treatment sludge and the human health risk associated with their consumption. Soil and vegetables samples were collected from farms with sludge and other samples from a farm where there were no sludge served as control. The soil samples were collected at random and analyzed for physicochemical properties, using a standard method and concentrations of the toxic elements both in soils and vegetables, As, Cd, Cr, Cu, Hg and Pb were analyze using Atomic Absorption Spectroscopy (AAS). The potential risk from the consumption of these vegetables was assessed using standard methods. The result showed a significant increase in physicochemical properties on soil with sludge over the control without sludge. The mean concentration of Cd and Hg in AC soil with sludge (3.61 and 3.28 mg/kg) and CO soil with sludge (3.27 and 3.39 mg/kg) respectively, were above the WHO/FAO permissible limits of 3.0 mg/kg Cd and 2.0 mg/kg Hg for soil except for other metals and the control soil samples which recorded a mean value that was below the permissible limit. The mean concentrations of As, Cd, Cr, Cu, Hg and Pb recorded in AC with sludge were 2.80, 2.00, 3.72, 4.08, 3.54 and 3.61 mg/kg respectively while CO with sludge were 2.89, 2.00, 3.64, 4.26, 3.48 and 3.09 mg/kg respectively which were above the WHO/FAO permissible limit of 0.5, 0.20, 0.3, 3.0, 0.1 and 0.3 mg/kg respectively for edible vegetables and are significantly different ($p<0.05$) from the controls. The mean values recorded at all control sites were below the FAO/WHO acceptable value except Cr which was above the WHO/FAO permissible limit of 0.3 mg/kg for edible plants. The HQ and HI shows that there is no harmful effect on the consumption of the vegetables since the values obtain were not greater than>1. The study concludes that soil around water treatment sludge and vegetables grown with water treatment sludge can bio accumulate toxic substance such as heavy metals which pose health risk from the consumption.

Keywords: *Amaranthus cruentus*, *Corchorus olitorius*, Toxic elements, Risk assessment, Sludge

INTRODUCTION

One of the biggest challenges in Nigeria and in most developing countries is the management of sludge produced by various water treatment processes and chemicals used in treatment. In Niger State, Nigeria because of rapid growing population, water treatment plants are facing the problem of treating highly loaded raw water (dissolved and suspended particles) and have to use diverse chemicals such as Alum, and chlorine in order to obtain drinking water which meets the fast growing population and acceptable health standards. Consequently sludge produced from water purification processes may contain high concentrations of those chemical removed by the purification processes (Uwimana et al., 2010).

Water treatment sludge (WTS) is produced in conventional drinking–water treatment processes as sedimentation including suspended and dissolved solids, organic matter, and other suspensions from the water. Due to these facts, the safe disposal of WTS has been becoming one of the main environmental concerns throughout the world due to the enormous quantity of sludge generated. Typically, disposal techniques such as soil application, river dumping, land filling, and incineration have been the common ways of disposal. Soil is the main reservoir of toxic elements and is the main source of pollution to the ecosystem at large. There are several pathways by which humans could be exposed to heavy metals contaminations. These could be through direct ingestion of the vegetables (food chain), direct ingestion of soil particles, dermal contact with soil particles, inhalation of soil dust and other particles from the air, oral and or dermal intake from groundwater (Liu et al., 2013).

There are several ways of treating sludge produced in a water treatment plant (WTP) to avoid the release of toxic chemicals into the environment, being the most commonly used methods the conditioning followed by thickening and dewatering through centrifuges, filters-press, drying ponds, etc. This treatment can be performed in or outside the WTP facilities (Sanchez et al., 2004). The treatment of water for public supply, which aims the separation and removal of impurities from the water itself, generates certain wastes (sludge). The amount of sludge generated during the treatment process depends on several factors, which includes the quality of raw water, the quality and dosage of coagulant used such as alum and chlorine, the cleaning and washing methods, the process automation, etc. (Di, 2005). According to standards, such waste should be properly treated before being discharged into the environment to avoid exposure of toxic elements.

The application of WTS in agriculture soils has been widespread in many countries. This practice has been shown to improve soil properties e.g. organic matter, nitrogen, phosphorus, micronutrients, nutrients content, porosity, aggregate stability, bulk density and water retention and result to increase plant productivity (Behbahaninia et al., 2009). WTS might contain not only organic matter but also potentially toxic elements (PTEs) such as Arsenic (As), Cadmium (Cd) Cromium (Cr), Copper (Cu), Mercury (Hg) and Lead (Pb). Heavy metals gradually accumulate in the soil, and the stability of heavy metals in the environment will cause accumulation and pollution since they could not be decomposed or are not biodegradable, like other organic pollutants through biological or chemical processes. Soils can be contaminated by the accumulation of PTEs and metalloids through emissions of WTS from the water treatment plant (Zhang et al., 2010).

Soils are the major sink for heavy metals released into the environment by anthropogenic activities and unlike organic contaminants which are oxidized to CO_2 by microbial action, most toxic elements do not undergo microbial or chemical degradation, and their concentration persists for a long time after their introduction. The high level of heavy metals in the soil could indicate similar concentration in plant by accumulation at concentrations causing serious risk to human health when consumed (Singh et al., 2010). Plants are exposed to heavy metals through the uptake of water from the contaminated soil; animals eat these plants; ingestion of plant-and –animal-based foods is the largest sources of heavy metals in human (Amadi et al., 2018). In human, exposure to high levels of heavy metals is known to pose severe health risk such as damage to the organs (such as liver, kidney), cancer and may result in death, and also pause risk for, animals, plant and whole environmental of our modern society (Farouk et al., 2008). Heavy metals can accumulate in organisms as they are hard to metabolize (process and eliminate) (Pezzarossa et al., 2011). Risk assessment is an effective scientific tool which enables decision makers to manage and control sites so contaminated in a cost-effective manner while preserving public and ecosystem health (Zhao et al., 2002).

Research has shown that the use of sludge can result in increased concentration of PTEs in soil at times to toxic levels. Heavy metals tend to accumulate along the food chain, with possible uptake in plants and livestock. Many people could be at a risk of adverse health effect from consuming vegetables cultivated in soil amended with WTS that is highly contaminated with toxic elements. This can pose a health effect to the economy (Steven and Edith, 2018). It is therefore important to monitor the heavy metals levels in sludge amended soil. The use of sludge from treatment plant in Chanchaga by small scale farmers may result to accumulation of toxic elements into the soils which can be absorbed by plants. In particular, it has been advocated that WTS could become a reusable product with great commercial potential. A number of constructive attempts and research efforts have been done particularly in recent years to reuse WTS in various beneficial ways such as coagulant and/or adsorbent for cleaning contaminants water, building materials of brick and concrete, land applications to improve soil quality, and other uses of animal feed, etc. (Taek–Keun et al., 2010).

Jute leaves (*Corchorus olitorius*) and African spinach (*Amaranthus cruentus*) also known as ayoyo, alayyafoo in Hausa, ewedu, efo tete in Yoruba and kerenkeren, inine in Igbo respectively. The leafy vegetables are mostly consumed by the Yoruba's in the western region of Nigeria where it is an important components of daily diets. Leafy-vegetables contain protein, essential minerals, fiber, vitamins, carotene and some essential amino acids required for normal metabolic activities of the body (Mavengahama, 2013;

Conrad et al., 2018). These nutrients help to repair worn out tissues, reduce cancer risks, lower cholesterol levels, normalize digestion time, improve vision, fight free radicals, and boost immune system activity. The vegetables also act as antioxidants that help to protect human body from oxidant stress, cardiovascular diseases and cancers (Santhakumar et al., 2018). In vegetables, these heavy metals can accumulate in edible parts (leaves and roots). PTEs are generally more mobile at pH<7 than at pH>7 (Bongekile et al., 2014; Fonge et al., 2017). However, they can pose a significant health risk to humans, leading to various chronic diseases, particularly in elevated concentrations or in prolonged dietary intakes (Drechsel et al., 2010; Tirima et al., 2016).

Farmers residing in this area exploit and take advantage of sludge discharge from water treatment plant for agricultural production. Heavy metals concentrations in soil and plant tissue may increase with the use of sludge for vegetable production posing threats to health of consumers. However, the sludge application may result in heavy metals accumulation in the soil. As a result, plants may absorb heavy metals from the soil above the permitted levels and enter the food chain affecting the human beings health (Arora et al., 2008). The proper management of sludge utilization must consider many aspects including its heavy metal content, crop type and its nutrient requirement, and biological and physicochemical properties of soil. These aspects are essential to determine the optimum rate, time and method of sludge application (Babu et al., 2014). Hence, this study was designed with the aim of determining the soil physicochemical changes, bioaccumulation of PTEs on soil and edible vegetables *Corchorus olitorius* (CO) and *Amaranthus cruentus* (AC) grown with WTS from Niger State water board treatment plant in Chanchaga Minna, Niger State, Nigeria and also the health risk associated with the consumption of this vegetables.

MATERIALS AND METHODS

Two commonly consumed leafy vegetables; Jute leaves (*Corchorus olitorius*) and African spinach (*Amaranthus cruentus*), were selected for the study. The vegetable leaves used for the study were harvested fresh from the sites located in Chanchaga Minna Niger State.

Study Area

The study was carried out in a farm close to the Niger State water board at Chanchaga, Bosso Local Government Area in North-central, Niger State of Nigeria from January to February 2019. Nigeria lies approximately between latitude 4 and 14 °North and longitude 3 and 15° East as shown in Figure 1. Chanchaga is situated at 9°34′ North latitude, 6°33′ East longitude, with an area of 72km^2 as shown in Figure 2 and a population of 201,429 at the 2006 census.

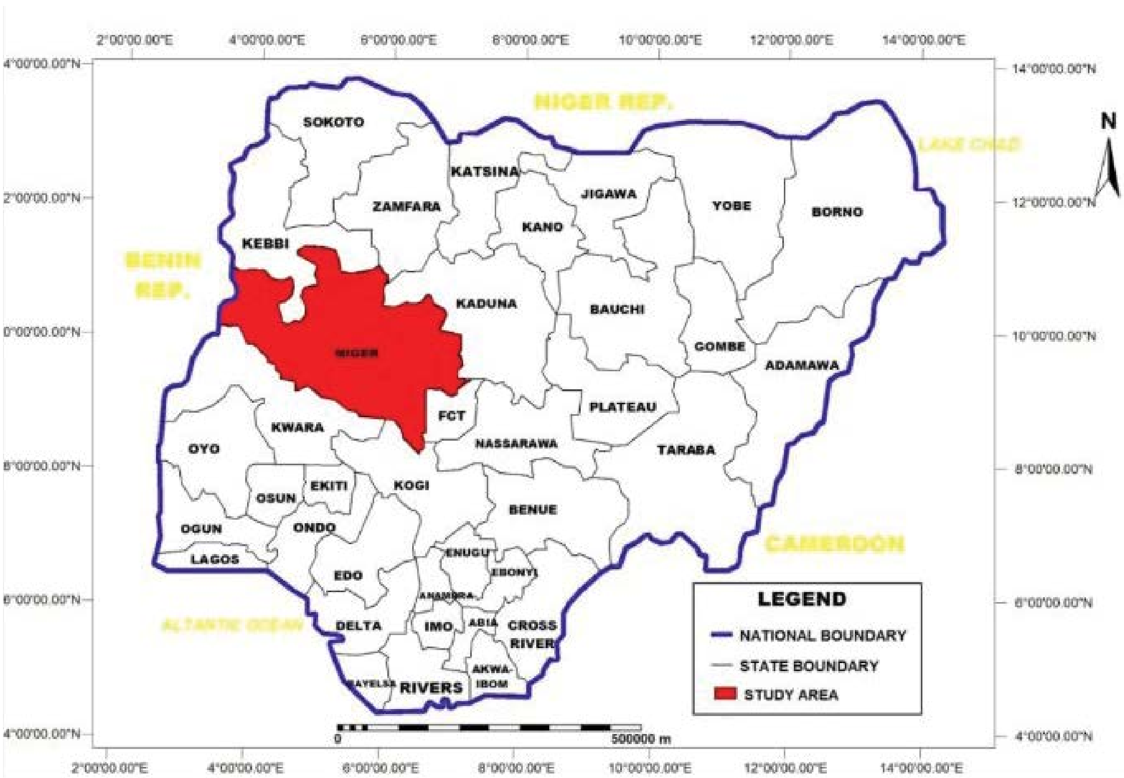

Figure 1: Map Nigeria showing Niger State in red

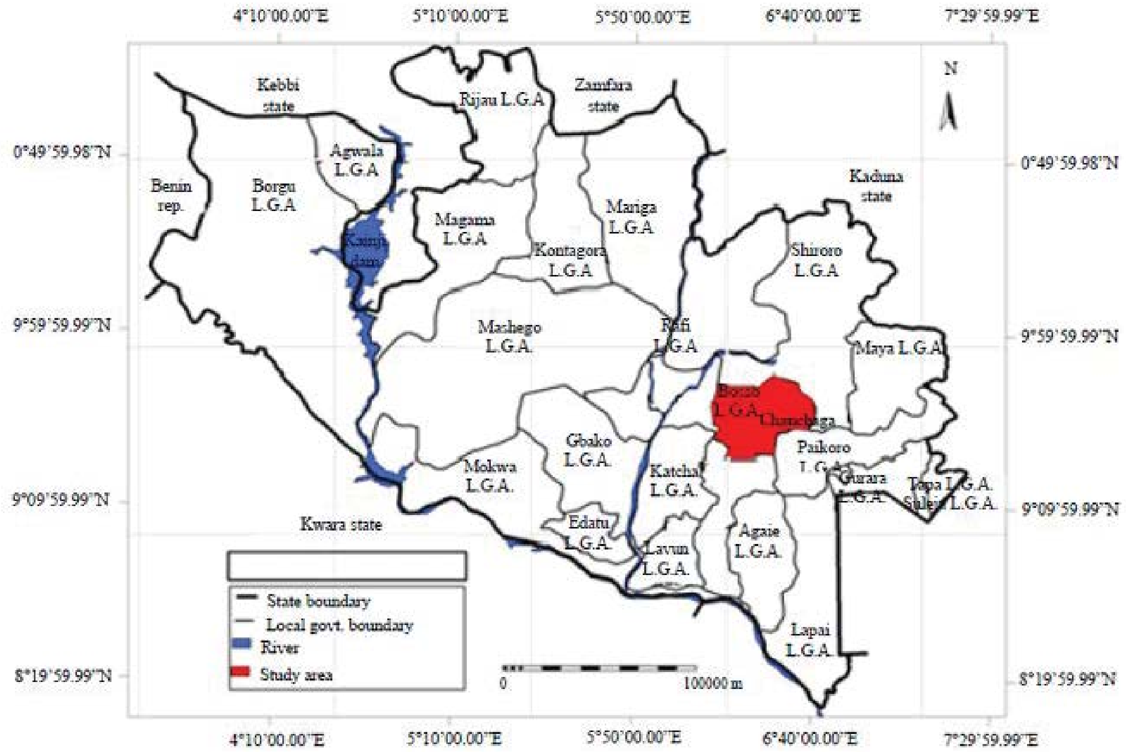

Figure 2: Map of Niger State showing study area in red

Experimental Design

A randomized complete block design with three replications for each sample was used to assess physicochemical properties of soil and the load of PTEs, on the leafy vegetables of Jute leaves (CO) and African spinach (AC). The physicochemical properties of the soil were done in five groups, from group 1 to 5, which are raw sludge, AC control soil, AC soil with WTS, CO control soil and CO soil with WTS respectively. The concentrations of the PTEs both in soils and vegetables, were done in four groups, from group 1 to 4, which are AC control soil and vegetables, AC soil and vegetables with WTS, CO control soil and vegetables, and CO soil and vegetables with WTS respectively. The samples were collected at random and analyzed for Physicochemical properties, pH, TN, TP, OM, TOC, K^+, Mg^+ and Na^+ and PTEs As, Cd, Cr, Cu, Hg and Pb.

Sample collection

Soil samples were collected using a hand soil auger in random replicates of three, at 20 cm depth and were bulked to form a composite sample from the control site (vegetable farm with no sludge application) and test site (TWS used as soil amendment), both in Chanchaga Minna Niger State, Nigeria. The samples were air-dried under room temperature 27°C to ensure constant weight for 3 days. Samples were homogenized using a ceramic mortar and pestle to obtain finer texture and to remove sticks, pebbles and rock particles. The homogenized soil samples were then sieved through a 2 mm polythene sieve and stored in a sample container prior to analysis. Vegetable Leaves were also randomly sampled within the farms (control leaves and test leaves) to get a representative sample. All samples were collected aseptically in a sterilized universal container and plastic bags.

Determination of the physico-chemical parameters

The soil pH samples were measured by potentiometric meter using a digital pH meter. Soil samples (10 g) were stirred with 100ml of distilled water with a glass rod and the pH of the suspension was recorded. Physicochemical parameters of the soil in all the groups were determined according to Nimyel et al., (2015). The physicochemical parameters measured in all the five groups were soil texture, pH, Total Organic Carbon, Organic Matter, Total Nitrogen, Total Phosphorus, and Exchangeable Cation (Na^+, Mg^{2+} and K^+). The Physico-chemical properties of the soil were analyzed in order to check the biodegradable process.

Determination of toxic elements

Samples of both soils and vegetables (1.00 ± 0.001g each) were placed into 100 ml beakers separately, to which 15 ml of tri-acid mixture (70% high purity HNO_3, 65%, $HClO_4$ and 70% H_2SO_4 in 5:1:1 ratio) were added. The mixture was digested at 800

C till the solution became transparent. The resulting solution were filtered and diluted to 50 ml using deionized water and analyzed for As, Cd, Cr, Cu, Hg and Pb, by atomic absorption spectrophotometry (Barau et al., 2018).

HUMAN HEALTH RISK ASSESSMENT

Estimation of Bioaccumulation Factor (BAF)

The transfer coefficient was calculated by dividing the concentration of toxic metals in vegetables by the total toxic metals concentration in the soil. This index of soil-plant transfer or intake of toxic elements from soil through vegetables was calculated using the following relationship described by Olowoyo et al., 2010.

$$BAF = C_{veg}/C_{soil} \quad (1)$$

Where; BAF represent the transfer factor of vegetable

C_{veg}= Toxic elements concentration in vegetable tissue, mg/kg fresh weight

C_{soil}=Toxic elements concentration in soil, mg/kg dry weight.

BAF>1 indicates that the vegetable are en-riched in elements from the soil (Bio-accumulation)

BAF<1 means that the vegetables excluded the toxic elements from soil (excluder).

Estimation of the Daily Intake of Metal (DIM)

The Daily intake of toxic elements was calculated using the following formula used by Olowoyo and Lion (2013).

$$ADDM = \frac{DI \times M_{veg}}{WB} \quad (2)$$

Where; ADDM=represents the average daily dose (mg,kg/d) of the metal

DI=is the daily intake of leafy vegetable (0.182 kg/d for adults and 0.118kg/d for children according to Nabulo et al., 2010)

M_{veg}=is the trace toxic elements (metals) concentration in the vegetables tissues (mg/kg)

WB=represent the body weight of investigated individuals (55.7kg for adults and 14.2 kg for children).

Estimation of the Potential Hazard of Metal to Human (Hazard Quotient HQ)

The Hazard Quotient (HQ) was used to calculate the possible human health risks associated with the consumption of vegetables harvested from the contaminated soils from Sewage areas. The following equation (Nabulo et al., 2010) for calculating human health risk from consumption of leafy vegetables used to calculate the Hazard Quotient of vegetables.

HQ is the ratio between exposure and the reference oral dose (RFD)

If the ratio is lower than one (1), there will be no obvious risk.

$$HQ = \frac{ADDM}{RFDM} \quad (3)$$

Where; ADDM=represents the average daily dose (mg, kg/d) of the metal

RFDM=is the reference dose of the metal (mg, kg/d)

RFDM=is define as the maximum tolerable daily intake of metal with no adverse effect.

Estimation of Hazard Index (HI)

The hazard index (HI) was calculated to determine the overall risk of exposure to all the heavy metals via the ingestion of a particular vegetable crop (USEPA, 2002). The hazard index (HI) was calculated as the summation of the hazard quotient (HQ) arising from all the metals examined. The value of the hazard index is proportional to the magnitude of the toxicity of the vegetables consumed. HI>1 indicates that the predicted exposure is likely to pose potential health risks. However, a hazard index>1 does not necessarily indicate that a potential adverse health effects will result, but only indicates a high probability of posing health risks.

$$HI = \sum HQ_{As} + HQ_{Cd} + HQ_{Cr} + HQ_{Cu} + HQ_{Hg} + HQ_{Pb} \quad (4)$$

STATISTICAL ANALYSIS

The data obtained were analysed using IBM Statistical Product and Service Solution (SPSS) version 20 and Microsoft excel 2013. The results were expressed as mean ± standard deviation (SD). One way analysis of variance (ANOVA) was carried out as $p<0.05$ considered statistically significant. Duncan's multiple range test (DMRT) was used to compare mean values of test groups and control as well as differences within group means of the various test groups.

RESULTS

Physicochemical Properties of Soil Samples

Table 1 presents the summary of the physicochemical properties of soil samples. The pH of the soil raw sludge, *Amaranthus cruentus* (AC) control soil, AC soil with sludge, *Corchorus olitorius* (CO) control soil, and CO soil with sludge were 5.04, 7.07, 5.85, 6.86 and 5.83 respectively. The total nitrogen in the soil with sludge were 3.71% and 3.86% while the controls were 2.52% and 2.32% on the AC and CO soil respectively. The total phosphorus content in the soil with sludge were 17.96% and 18.82% while the controls were 19.26% and 20.10% on the AC and CO soil respectively. The soil Organic matter and total organic carbon in the soil with sludge ranges from 5.18 to 6.02% while the control soil ranges from 2.31 to 2.72%. The exchangeable cations K^+, Mg^{2+} and Na^+ in AC control soil, AC soil with sludge, CO control soil, and CO soil with sludge were (2.81, 10.65, 7.37), (2.09, 9.83, 6.77), (2.88, 11.03, 7.45) and (1.94, 8.92, 6.52 Meg/100 g) respectively as shown in Table 1.

Results expressed as Mean ± SD. Mean values with same superscript letters on the rows are considered not significant (P>0.05). n=3

Heavy metal concentration in soils samples

Table 2 presents the summary of the mean concentrations (mg kg^{-1}) of heavy metals Arsenic (As), Cadmium (Cd) Cromium (Cr), Copper (Cu), Mercury (Hg) and Lead (Pb) analysed in the soil samples of AC control Soil, AC soil with sludge, CO control soil and CO soil with sludge. The mean concentration of Cd and Hg in AC soil with sludge (3.61 and 3.28 mg/kg) and CO soil with sludge (3.27 and 3.39 mg/kg) respectively were above the WHO/FAO (2001) permissible limits of 3.0 mg/kg Cd and 2.0 mg/kg Hg for soil except for control soil which recorded a mean value that was below the permissible limit. The concentrations of As and Cr recorded ranged from 2.15 to 5.84 and 2.29 to 5.89 mg/kg respectively which was below the WHO/FAO (2001) permissible limit of 20 mg/kg As and 100 mg/kg Cr for soil. The concentrations of Cu and Pb recorded ranged from 1.53 to 6.79 and 2.36 to 3.07 mg/kg respectively which was below the WHO/FAO (2001) permissible limit of 100 mg/kg Cu and 50 mg/kg Pb for soil shown on Table 2.

Heavy metal concentration in *Amaranthus cruentus* and *Corchorus olitorius* amended with sludge and controls

Table 3 presents the summary of the mean concentrations (mg kg) of heavy metals Arsenic (As), Cadmium (Cd) Cromium (Cr), Copper (Cu), Mercury (Hg) and Lead (Pb) analysed in *Amaranthus cruentus* and *Corchorus olitorius* grown on sludge contaminated soil and a control with no sludge. The concentrations of As and Cd recorded in AC and CO with sludge were As (2.80), As (2.00 mg/kg) and Cd (2.89), Cd (2.00 mg/kg) which was above the WHO/FAO (2016) permissible limit of 0.5 mg/kg and 0.20 mg/kg respectively for edible vegetables. The concentrations of Cr and Cu recorded in AC and CO with sludge were Cr (3.72), Cr (4.80 mg/kg) and Cu (3.64), Cu (4.26 mg/kg) which was above the WHO/FAO (2016 and 1984) permissible limit of 0.3 mg/kg and 3.0 mg/kg respectively for edible vegetables.

The concentrations of Hg and Pb recorded in AC and CO with sludge were Hg (3.54), Hg (3.61 mg/kg) and Pb (3.48), Pb (3.09 mg/kg) which was above the WHO/FAO (2016) permissible limit of 0.3 mg/kg and 0.1 mg/kg respectively for edible vegetables as shown in Table 3.

Results expressed as Mean ± SD. Mean values with same superscript letters on the rows are considered not significant (P>0.05). PL=Permissible limit. n=3.

Estimation of Bioaccumulation Factor (BAF)

Table 4 shows the Bioaccumulation factor (BAF) of heavy metals from the soil to plants, which is the ratio of the concentration of metals in plants to the total concentration in the soil. All the control samples, and other metals were below one (<1) which indicate that the vegetable do not take up toxic element from the soil except Hg and Pb which are above one (>1). The highest BAF value obtained in AC and CO with sludge were Hg (1.09), Pb (1.22) and Hg (1.02),

Table 1: Physicochemical properties of soil samples

Soil Properties	Raw sludge	AC soil without sludge (Control)	AC soil with sludge	CO soil without sludge (control)	CO soil with sludge
Texture	Sandy loamy	Loamy	Sandy loamy	Loamy	Sandy loamy
pH	5.04 ± 0.03[d]	7.07 ± 0.05[a]	5.85 ± 0.06[c]	6.86 ± 0.03[b]	5.83 ± 0.02[c]
TN %	4.26 ± 0.02[a]	2.52 ± 0.04[d]	3.71 ± 0.03[c]	2.32 ± 0.08[e]	3.86 ± 0.07[b]
TP %	20.82 ± 0.04[a]	19.26 ± 0.07[c]	17.96 ± 0.15[e]	20.10 ± 0.11[b]	18.82 ± 0.10[d]
TOC %	5.84 ± 0.03[a]	2.31 ± 0.03[e]	5.18 ± 0.03[c]	2.41 ± 0.03[d]	5.53 ± 0.08[b]
OM %	6.29 ± 0.01[a]	2.72 ± 0.08[c]	6.02 ± 0.06[b]	2.34 ± 0.03[d]	5.94 ± 0.04[b]
K^+ meq/100g	3.55 ± 0.03[a]	2.81 ± 0.05[c]	2.09 ± 0.03[d]	2.88 ± 0.03[b]	1.94 ± 0.04[e]
Mg^{2+} meq/100g	8.67 ± 0.04[e]	10.65 ± 0.04[b]	9.83 ± 0.04[c]	11.03 ± 0.08[b]	8.92 ± 0.06[d]
Na^+ meq/100g	8.92± 0.04[a]	7.37 ± 0.04[b]	6.77 ± 0.04[c]	7.45 ± 0.04[b]	6.52 ± 0.08[d]

Table 2: Heavy metal concentration in soils with sludge and control soils

Heavy Metals (mg/kg)	Soil samples				
	AC Control Soil	AC with sludge	CO Control Soil	CO with sludge	PL(mg/kg) in soil FAO/ WHO,2001
As	2.20 ± 0.08[c]	5.70 ± 0.06[b]	2.15 ± 0.03[c]	5.84 ± 0.04[a]	20
Cd	0.98 ± 0.06[c]	3.61 ± 0.02[a]	0.58 ± 0.04[d]	3.27 ± 0.02[b]	3
Cr	2.48 ± 0.03[c]	5.89 ± 0.08[a]	2.29 ± 0.01[d]	5.67 ± 0.03[b]	100
Cu	1.53 ± 0.02[d]	6.58 ± 0.04[b]	1.87 ± 0.05[c]	6.79 ± 0.05[a]	100
Hg	0.24 ± 0.01[d]	3.28 ± 0.07[b]	0.36 ± 0.02[c]	3.39 ± 0.07[a]	2
Pb	2.59 ± 0.05[c]	2.95 ± 0.03[b]	2.36 ± 0.03[d]	3.07 ± 0.02[a]	50

Results expressed as Mean ± SD. Mean values with same superscript letters on the rows are considered not significant (P>0.05). PL= Permissible limit. n=3

Table 3: Heavy Metal Concentration in *Amaranthus cruentus* and *Corchorus olitorius* amended with sludge and controls

Heavy Metals (mg/kg)			Samples		
	AC control	AC with sludge	CO control	CO with sludge	PL(mg/kg) in plant FAO / WHO,2016*, 1984**
As	0.47 ± 0.01[b]	2.80 ± 0.08[a]	0.35 ± 0.03[c]	2.89 ± 0.08[a]	0.5*
Cd	0.17 ± 0.01[b]	2.00 ± 0.05[a]	0.18 ± 0.01[b]	2.00 ± 0.02[a]	0.2*
Cr	0.87 ± 0.01[b]	3.72 ± 0.10[a]	0.95 ± 0.05[b]	3.64 ± 0.07[a]	0.3*
Cu	0.39 ± 0.01[d]	4.08 ± 0.02[b]	0.56 ± 0.02[c]	4.26 ± 0.02[a]	3.0**
Hg	0.08 ± 0.01[c]	3.54 ± 0.03[a]	0.07 ± 0.01[c]	3.48 ± 0.02[b]	0.1*
Pb	0.19 ± 0.01[c]	3.61 ± 0.07[b]	0.18 ± 0.01[c]	3.09 ± 0.01[a]	0.3*

Pb (1.01) respectively which indicates that the vegetable are en-riched in elements from the soil (Bio-accumulation). The calculations was done using eqn. (1) .

Table 4: Estimation of Bioaccumulation Factor (BAF)

Heavy Metals (mg/kg)		BAF		
	AC control	AC with sludge	CO control	CO with sludge
As	0.21	0.49	0.16	0.49
Cd	0.17	0.55	0.31	0.61
Cr	0.35	0.63	0.41	0.64
Cu	0.25	0.62	0.29	0.62
Hg	0.33	1.07	0.19	1.02
Pb	0.07	1.22	0.07	1.01

TF>1 indicates that the vegetable are en-riched in elements from the soil (Bio-accumulation).

TF<1 means that the vegetables exclude the element from soil (Excluder).

Daily Intake, Potential Hazard of Metal (Hazard Quotient) individual

Table 5 shows the hazard quotient and Daily intake was calculated for both adults and children from trace metals in leaves of *Amaranthus cruentus* and *Corchorus olitorius*. The highest DIM obtained from AC and Co vegetables was all in children with Pb (0.030) and Cu (0.035) respectively using equation (2). The highest HQ of heavy metal in *Amaranthus cruentus* and *Corchorus olitorius* amended with water treatment sludge for both adult and children were in Mercury (Hg). Adult (0.116, 0.14), children (0.294 and 0.289 respectively) using eqn. (3).

CO: *Corchorus olitorius*, DIM: Daily Intake of Metal; HQ: Hazard Quotient

Estimation of hazard index (HI) of metal for individuals

The calculated HI for both Adult and children in both *Amaranthus cruentus* (AC) and *Corchorus olitorius* (CO)

Table 5: Daily Intake, Potential Hazard of Metal (Hazard Quotient) individual

Heavy Metals	Individuals	DIM and HQ for individuals				
		Hazard	AC control	AC with sludge	CO control	CO with sludge
As	Adult	DIM	0.001	0.009	0.001	0.009
		HQ	0.003	0.018	0.002	0.019
	Children	DIM	0.003	0.023	0.003	0.024
		HQ	0.007	0.046	0.006	0.048
Cd	Adult	DIM	0.001	0.006	0.001	0.007
		HQ	0.003	0.032	0.003	0.033
	Children	DIM	0.001	0.017	0.001	0.017
		HQ	0.007	0.083	0.007	0.083
Cr	Adult	DIM	0.003	0.012	0.003	0.012
		HQ	0.009	0.041	0.01	0.04
	Children	DIM	0.007	0.031	0.008	0.03
		HQ	0.024	0.103	0.026	0.1
Cu	Adult	DIM	0.001	0.013	0.002	0.014
		HQ	0	0.004	0.001	0.005
	Children	DIM	0.003	0.034	0.005	0.035
		HQ	0.001	0.011	0.002	0.012
Hg	Adult	DIM	0	0.012	0	0.011
		HQ	0.003	0.116	0.002	0.114
	Children	DIM	0.001	0.029	0.001	0.029
		HQ	0.017	0.294	0.006	0.289
Pb	Adult	DIM	0	0.012	0.001	0.01
		HQ	0.002	0.04	0.002	0.034
	Children	DIM	0.002	0.03	0.001	0.026
		HQ	0.005	0.1	0.005	0.086

Table 6: Estimation of hazard index (HI) of metal for individuals

		HI for Individuals			
	Individuals	AC control	AC with sludge	CO control	CO with sludge
	Adult	0.02	0.25	0.02	0.25
HI=∑HQ (HM)	Children	0.05	0.64	0.05	0.62

HI: Hazard index; ∑: Summation of the Hazard Quotient (HQ) arising from all the heavy metals(HM) examined.

AC: *Amaranthus cruentus;* CO: *Corchorus olitorius*

amended with sludge and also control without sludge were all less than 1. The highest value obtain in the vegetables amended with sludge were in children AC (0.64) and CO (0.62) using eqn. (4)

DISCUSSION

Physicochemical Properties of Soil Samples

The low pH (5.04, 5.85 and 5.83) which moves toward acidity at raw sludge, AC soil with sludge and CO soil with sludge respectively indicate that PTEs are generally more mobile at pH<7 than at pH>7 (Bongekile et al., 2014; Fonge et al., 2017). However, they can pose a significant health risk to humans, leading to various chronic diseases, particularly in elevated concentrations or in prolonged dietary intakes (Drechsel et al., 2010; Tirima et al., 2016). The low pH of the soils with sludge may probably be due to the water treatment sludge use as soil amendment. This indicates a significant increase of total nitrogen content in the soil amended with sludge. This indicates a significant decrease in total phosphorus content in the soil amended with sludge. The results showed that Organic matter and total organic carbon in the soil with sludge were generally higher than that of the control samples. Which indicate that the sludge contain high organic matter and organic carbon which increases the soil nutrient and make it fertile. The Analysis of variance (ANOVA) carried out revealed significant differences (p<0.05) in the soil amended with sludge and soil with no sludge as shown in Table 1. This result changes the soil physicochemical properties, especially the soils amended with WTS. This increases the heavy metals in the soil, which is then likely transferred to plants that grow on such soils, with the associated risks of long term toxicity to humans that consume them and other biota in the ecosystem.

Heavy Metal Concentration in Soils Samples

The study revealed that the concentrations of most of the elements were significantly (p<0.05) higher at the soil with sludge compared to the control soil samples as shown in Table 2. One-way Analysis of variance (ANOVA) revealed a significant (p<0.05) variation in the concentrations of the four (4) groups analyze for elements in the soil, which is an indication of the extent of metal pollution in the soils. The high concentration of metals in the soil amended with water treatment sludge could be attributed to the application of sludge which contain high concentrations of those chemical removed by the purification processes as indicated earlier. This result is similar to the findings of Steve and Edith (2018) which recorded extremely high concentrations of heavy metals on soil amended with sludge in Obunga Slum, Kisumu County, Kenya. Toxic elements exhibit toxic effects towards soil biota by affecting key microbial processes and decrease the number and activity of soil microorganisms. According to Chen et al., 2010 the heavy metals caused a decrease in bacterial species richness and a relative increase in soil actinomycetes or even decreases in both the biomass and diversity of the bacterial communities in contaminated soils.

Heavy Metal Concentration in *Amaranthus cruentus* and *Corchorus olitorius* Amended with Sludge and Controls

One-way Analysis of variance (ANOVA) revealed a significant (P<0.05) variation in the concentrations of heavy metals in the vegetables AC and CO amended with sludge and that of the controls. Generally AC and Co amended with sludge had higher heavy metals concentrations than the controls. Vegetables from sludge contaminated soil exceed the WHO/FAO permissible limit of metal in edible vegetable. The mean values recorded at all control sites were below the FAO/WHO acceptable value except Cr which was above the WHO/FAO (1984) permissible limit of 0.3 mg/kg for edible plants. The sequence of occurrence mean concentrations of the heavy metals in AC and CO grown on contaminated sludge soil decreased in the order Cu>Cr>Pb>Hg>As>Cd and Cu>Cr>Hg>Pb>As>Cd respectively in Table 3. Heavy metals and nutrients absorbed by the roots are usually trans located and allocated to different parts of the plants which could limit the concentrations in the leaves. However, availability of metals in the soil and continuous absorption by the roots could lead to higher concentration in the leaves.

The high concentration of As and Cd at amended soil with sludge might be as a result of the chemicals contain in the sludge use. Arsenic affects almost all organs during its acute or chronic exposure. Liver has been reported as target organ of arsenic toxicity. Toxicity is due to arsenic's effect on many cell enzymes, which affect metabolism, DNA repair and brain problem. The most prominent chronic manifestations of as involve the skin, lungs, liver and blood systems. According to Liu et al. (2013) atmospheric deposition is a major factor for high metal accumulation in plant samples, and this could therefore be the cause of the as in the samples analyzed. Significant concentration of Cd may have gastrointestinal effect and reproductive effect on livestock (Maobe et al., 2012). Jabeen et al., (2010) reported that cadmium causes both acute and chronic poisoning, adverse effect on kidney, liver, vascular and the immune system.

The high concentration of Cr and Cu at amended soil with sludge could be attributed to continuous usage of purification chemicals. In a similar study, Benedicta, et al. (2017) find that the concentration of Cu from all the site S1 (95.56), S2 (10.13), S4 (6.92) and S5 (5.48) were all above the FAO/WHO (1984) permissible limit of 3.0 mg/kg at Korle Lagoon area in Accra, Ghana. High dose of chromium is observed to cause Bronchopneumonia, chronic bronchitis, diarrhea, emphysema, headache, irritation of the skin, itching of respiratory tract, liver diseases, lung cancer, nausea, renal failure, reproductive toxicity, and vomiting. In plant it causes chlorosis, delayed senescence, wilting, biochemical lesions, reduced biosynthesis germination, stunted growth, and oxidative stress (Barakat, 2011). Copper is indeed essential, but in high doses it can cause anemia, diarrhea, headache, metabolic disorders, nausea, vomiting, liver and kidney damage, stomach and intestinal irritation on human health . In plant it can lead to chlorosis, oxidative stress, and retarded growth, while in microorganism, it can disrupt cellular function, and inhibit enzyme activities (Dixit et al., 2015). According to Maobe et al. (2012) high levels of copper can cause metal fumes fever with flu-like symptoms, hair and skin discoloration, dermatitis, irritation of the upper respiratory tract, metallic taste in the mouth and nausea.

The high concentration of Hg and Pb may be due to the sludge use in the area which contains purification chemicals. Mercury is not essential for plant growth (Lange et al., 2013). Mercury poisoning symptoms include blindness, deafness, brain damage, digestive problems, kidney damage, lack of coordination and mental retardation. The ability of plants to accumulate essential metals equally enables them to acquire other nonessential metals (Djingova and Kuleff, 2000). Khan et al., (2008) reported that lead causes both acute and chronic poisoning and thus, poses adverse effects on kidney, liver, vascular and immune system. Lead can cause serious injury to the brain, nervous system, red blood cells, low IQ, impaired development, shortened attention span, hyperactivity, mental deterioration, decreased reaction time, loss of memory, reduced fertility, renal system damage, nausea, insomnia, anorexia, and weakness of the joints when exposed to high lead. In plant, lead affects photosynthesis and growth, chlorosis, inhibit enzyme activities and seed germination (Nagajyoti et al., 2010).

Generally Heavy metals or toxic elements present in this study can cause severe problems. This Study revealed that vegetable crops AC and CO have the ability to uptake the heavy metals through their roots and transport them to the edible portion of the plant because high concentrations were observed in the soil.The differences in the accumulation of these metals in the vegetables under study could be attributed and not limited to the varying physiological phenomenon such as absorption rate of different metals viz a viz soil physicochemical properties, choice of plants in selecting which mineral is allocated and stored in its parts among other factors (Alloway, 1990). The bio-accumulated heavy metals on the leaves of *Amaranthus cruentus* and *Corchorus olitorius* may interact directly with biomolecules such as nucleic acid, protein, carbohydrate, disrupting critical biological processes, resulting in toxicity and the concomitant transfer of these metals through the food chain could ultimately pose risk to human life (Basapor and Ngabaza, 2015; Gall et al., 2015; Huang et al., 2017) shown in Table 3.

Estimation of Bioaccumulation Factor (BAF)

The BAF for the same metal in the farm lands were significantly different from those for control and according to the type of plants. Plants are known to take up and accumulate trace metals from contaminated soil (Opaluwa et al., 2012). The soil-plant BAF of different heavy metals in AC and CO with sludge showed the following decrease order -$BAF_{Pb>}BAF_{Hg>}BAF_{Cr>}BAF_{Cu>}BAF_{Cd>}BAF_{As}$ and $BAF_{Hg>}BAF_{Pb}$ $_{>}BAF_{Cr>}BAF_{Cu>}BAF_{Cd>}BAF_{As}$ respectively. The bioaccumulation factor depend on different species of plants, some plant have the ability to accumulate more metals from the soil than others. Where BAF>1 indicates the vegetable are enriched in elements from the soil (Bio-accumulation). BAF<1 means that the vegetables exclude the element from soil (Excluder) shown in Table 4.

Daily Intake, Potential Hazard of Metal (Hazard Quotient) individual

The daily intake of heavy metals (DIM) was estimated according to the average vegetable consumption. The estimated DIM through the food chain is given in Table 5, for both adults and children. The DIM values for heavy metals were significantly high in the vegetables amended with sludge than the controls grown with no sludge. The highest DIM indicates that children are liable to be effected by the continuous consumption of these vegetables grown with treatment water sludge. The HQ of metals through the consumption of vegetables for both adults and children were given in Table 5. The HQ values for heavy metals were significantly high in *Amaranthus cruentus* and *Corchorus olitorius* amended with sludge than the controls. The decrease sequence of metals occurrence in HQ for both vegetables is Hg>Pb>Cr>Cd>As>Cu. The high values of Hg indicate that children had the highest values and can cause risk if consume continuously. In all the metal calculated HQ shows that there is no harmful effect on the consumption of the vegetables since the values obtain were not greater than>1. But continuous consumption can accumulate in the food chain shown in Table 5.

Estimation of Hazard Index (HI) of Metal for Individuals

The result showed that children are more likely to be affected with continuous consumption of *Amaranthus cruentus* and *Corchorus olitorius* grown on sludge. The result of this study regarding the HI revealed that AC and CO vegetable grown with sludge are safe for consumption because the values obtain were not greater than one shown in Table 6.

CONCLUSION

The soils and vegetation samples from the study area recorded significant levels of heavy metals, especially those amended with treatment water sludge. The results showed that all the six heavy metals (As, Cd, Cr, Cu, Hg and Pb) analyzed were present in soil and in the vegetable samples. The concentration of heavy metals in *Amaranthus cruentus* and *Corchorus olitorius* amended with sludge exceeded the WHO/FAO permissible limits in edible vegetable while the controls were within the permissible limit. This study concludes that soil around water treatment sludge and vegetables grown with water treatment sludge can bio accumulate toxic substance such as heavy metals which pose health risk from the consumption. Farmers in such water treatment plant areas need to break the habit of using the waste sludge on their farm land despite the advantages on the increase yield. The bioaccumulation factor for the vegetable showed that they exclude the element from soil (Excluder) i.e., the bioaccumulation factors are less than one. The HQ and HI shows that there is no harmful effect on the consumption of the vegetables since the values obtain were not greater than>1. But continuous consumption can accumulate in the food chain.

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