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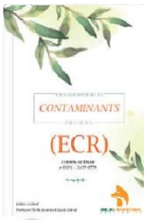

RESEARCH ARTICLE

HEAVY METALS CONCENTRATION IN SEDIMENTS AND BIOACCUMULATIONS IN CATFISH (*SILURIFORMES*) AND TOMATO FRUIT (*LYCOPERSIUM ESCALENTUM*) FROM UNRECLAIMED MINING PITS

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ABSTRACT

The study examined the levels of selected heavy metal in sediments and their bioaccumulation in catfish (*Oreochromis niloticus*) and Tomatos (*Lycopersium escalentum*) from selected unreclaimed mining pits used for irrigation and fish farming in Bukuru town, Jos south Local Government Area "L.G.A" Plateau State. Five (5) unreclaimed ponds were purposively selected; sediment, fish and tomato samples were collected from January to September, with January to March representing dry season and April to September as rainy season. Thirty-two (32) water samples were collected across the study area, while six (6) samples of fish and tomato were collected, three (3) for each season in addition to two controls sampled for different seasons. Samples were analyzed for Cd, Mn, Hg, Cu, Ni, Pb, Ur and Zn. All the heavy metal parameters except Zn, exceeded levels observed at control point as well as maximum permissible limits in the rainy season. Comparison of mean seasonal levels of heavy metals in sediment samples with control, revealed statistical difference at $\rho < 0.05$, $d = 0.007$. Similar pattern was observed for the dry season at $\rho > 0.05$, $d = 0.008$, an indication that the level of heavy metals presence in sediment samples from unreclaimed mining pits is statistically higher than levels at control point, irrespective of season. Similar results were obtained for Catfish in both seasons ($\rho < 0.05$, $d = 0.006$ and $\rho < 0.05$, $d = 0.02$) and Tomatoes ($\rho < 0.05$, $d = 0.003$ and $\rho < 0.05$, $d = 0.04$). These sites should be urgently reclaimed using approved reclamation techniques to eradicate the adverse health impact of consumption of the fruits, animal protein and vegetables cultivated at the sites.

KEYWORDS

Mining pits, Heavy metals, Sediment, Catfish, Tomato

1. INTRODUCTION

Illegal mining and mineral processing activities modify the environment negatively in a variety of ways because no legislation protecting the environment are followed. Many of the countries of the world including the United States have no specific legislation regulating mining and mineral processing activities until recently (Carla, 2006). Jos Plateau, Nigeria where mining has been reported ever since the pre-colonial era have no specific legislation regulating mining and mineral processing activities until 1949 (Stephen, 2007). Also, in some instances where these legislations exist, they are not being appropriately implemented or enforced. The rapid industrialization and intensive agricultural activities over the last few decades have resulted in the accumulation of various pollutants in the environment, especially heavy metals. Sediments play an essential role in terms of maintaining the structure and function of aquatic ecosystems (MacDonald et al., 2003). Sediments are an integral part of the aquatic environment providing habitat, feeding and rearing areas for shellfish, fish and other fauna (EPA, 1996). Considering the important roles sediment plays in marine environment, it is undisputed that sediments represent essential elements of aquatic environments (Balogun, 2017).

Sediments also serve as sink and sources of organic and inorganic materials in water bodies (Barron, 1995). Sediments contain many contaminants and therefore pose the highest risk to the aquatic environment as a source of pollution (Bervoets et al., 1994). Their remediation proves to be problematic due to the persistence and non-degradation of heavy metals in the environment (Yuan, et al., 2004). Heavy metal pollution in aquatic environment is greatly reflected by higher metal concentrations of heavy metals in biota can be linked to high concentration in sediments (Balogun, 2015). The bioavailability of metal loads in sediments influences the distribution and composition of benthic assemblage of aquatic bodies (Kress et. al., 2004). The most obvious effects of sediment contamination are the reduction in the diversity of biological species that are unable to tolerate the toxicants (Okoro et al., 2012).

Heavy metals are ill-defined subsets of elements that exhibit metallic properties and include the transition metals, some metalloids, lanthanides, and actinides (Adeboye, 2012). Heavy metals are also defined as one of the common transition metals, such as copper, lead, and Zinc (Carla, 2006). Heavy metals cause environmental pollution from sources such as lead petrol, industrial effluents, and leaching of metal ions from the soil into lakes and rivers through mining activities and acid rain. Living

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organisms require varying amounts of heavy metals such as iron, cobalt, copper, manganese, molybdenum, and zinc. All metals are toxic at higher concentrations. Excessive levels can be damaging to organisms. Other heavy metals such as mercury, plutonium, and lead are toxic metals that have no known vital or beneficial effect on organisms, and their accumulation over time in the bodies of animals can cause serious illness (Carla, 2006).

Certain elements that are normally toxic to some organisms under certain conditions are beneficial to others and examples of such elements include vanadium, tungsten, and even cadmium (Reena, 2011). Heavy metals are some of the most critical threats to the soil and water resources, as well as to human health. Pollution with heavy metals can affect the whole environment, but a major environmental concern and the longest lasting effects due to anthropogenic activities is the contamination of soils and water (Saeed, 2014). These metals are released into the environment through mining, smelting of metal ores, industrial emissions, and the application of pesticides, herbicides, and fertilizers. Metals, such as Cd, Cu, Pb, Zn and metalloids (such as Arsenic – As), are considered environmental metallic pollutants, due to their persistence, bio-accumulative nature thereby causing serious health problems to human and other animals.

The promulgation of the Mineral Act in 1946 in Nigeria for example, though paved way for the reclamation of mined out lands in the Jos Plateau like in some other parts of Nigeria however, meaningful reclamation efforts did not begin until 1949 thereby leaving many unreclaim mine dumps which are unsightly, and many times constitute death traps (Now Nigeria Mineral Act 1999; Komolafe, 2002). In addition, these unreclaim or abandoned mines which become mining ponds are sometimes so deep that they are recharged by groundwater, thus making them permanent water bodies with high potentials for irrigation, fisheries, water supply and recreation (Adeboye, 2012). These unreclaim mining ponds with their adjoining mine tailings are also potential source of heavy metals which are very toxic to humans. In Bukuru and Rayfield of Jos South Local Government Area, Plateau State, relicts of unreclaim or abandoned tin mines and tin ore processing sites abound. Mine tailings from the processing of the tin ore (often associated with Pb, ZnS ores) are disposed indiscriminately.

Unreclaim mining pits which subsequently become mining lakes and the water used for irrigation and fishing are also potential sources of heavy metals (Lar et al., 2014). These toxic substances could reach human beings through various absorption pathways of ingestion, bodily contact, and diet through the soil-food chain, inhalation, and oral intake. In a soil-vegetable or soil-grain system, diet dominates the exposure pathways of heavy metals to humans. Soil and water are important sources of heavy metals in crops and vegetables since the plant's roots can absorb these pollutants from them, and transfer same to the seeds. In addition to soil and water contamination by heavy metals resulting from mining and mineral processing without adequate reclamation, there is also the rapid reduction of arable land which poses an often overlooked but no less critical threat to food security (Saeed, 2014).

Thus, the pathways for human exposure to heavy metals contaminated soils and water through the food chain are of great concern. The Jos area is predominantly granitic consisting mainly of the younger granites ring complexes overlain by basaltic volcanic rocks which have been decomposed to lateritic soil. This soil contains heavy metals such as Pb, Ni, Cd, Cu, Fe, Hg, Zn, Mn and Ar with high potential to contaminate the vegetables grown on them (Lar et al., 2014). The water in the mining ponds can likewise contaminate these vegetables and/or the fish inside them. Vegetables and fish constitute essential diet component by contributing protein, vitamin, iron, calcium, and other nutrients, which are usually in short supply thereby leading to their high demand but with their attendant high levels of heavy metals toxicity.

The aim of this study is to assessed heavy metals in the soil, water and from few selected agricultural and aquatic products (tomatoes, lettuce; tilapia and catfish) from unreclaim mining ponds in Bukuru and Rayfield, Jos South Local Government Area of Plateau State as well as their implications on human health.

2. LITERATURE REVIEW

Hundreds of new chemicals are created by industrial scientists each year (Carla, 2006). Many of the inorganic industrial pollutants of particular concern are potentially toxic metals. Manufacturing, mining, and mineral-processing activities can all increase the influxes of these naturally occurring substances into the environment and locally increase concentrations from harmless to toxic levels. A common feature to all heavy metals is that they easily accumulate in the bodies of organisms that ingest them (Mason, 2000). Therefore, their concentrations increase up the food chain. Some marine algae may contain heavy metals at concentrations of up to 100 times that of the water in which they are living (Laws, 2000). Small fish eating the algae develop higher concentrations of heavy metals in their flesh; larger fish who eat the smaller fish concentrate the metals still further.

According to Carla the word reclamation is often preferred to restoration or rehabilitation in the various processes involved in making a previously bad or abandoned land good (Carla, 2006). This is because if the dictionary meaning of this word is applied to land that has been or is being mined by surface methods; only reclamation accurately describes the objective of bringing the land back to the desired condition. This therefore acknowledges the two essential features of land reclamation: that the desired condition should be specified at the onset, and that the desired condition be adapted to the possibilities of the specific situation. Restoration, which means to bring the land back to its original condition, in the strict meaning of the word is impossible (Mason, 2000). This is because something has been taken away that is not put back. For example, if the swell of the ground that is replaced happens by coincidence to make good the loss in volume and permits the restoration of former surface levels, the porosity of the soil, and therefore its capacity to hold and transmit water, would have been altered. Rehabilitation on the other hand is inappropriate in its original meaning in mining context but in its acquired meaning has much the same significant as reclamation (Mohammed, 2014).

According to French and Ngaji, reclamation has a process covers two situations: the recovery of land disturbed by former mining operations before reclamation was required by law or public demand (French and Ngaji, 2012). This is a form of post-mining land reclamation, the continuing process of reclaiming land during the mining operation as a part of the regular cycle of mining. This is a form of progressive land reclamation. It should be noted however that the term "land" is used in its wide sense to include hydrology and sometimes plant cover. The reclamation of old abandoned workings differs in some respects from that of the ongoing operations. The topsoil would have been buried in the dump. Re-vegetation may require the building up of a new soil depending on the chemical and physical properties of the spoil on the surface of the dumps and the way in which it has weathered. These considerations are likely to decide the post-reclamation use of the land. The complete filling of the old workings and the leveling of the surface; if it is required; makes the operation costly. Measures may be limited to the improvement of appearance and amenity and if possible, the establishment of some economic or social use for the land.

Water quality is changed and affected by natural processes and human activities. Generally natural water quality varies from place to place, depending on seasonal changes, climate changes and with the types of soils, rocks and surface through which it moves. A variety of human activities e.g. agricultural activities, urban and industrial development, mining and recreation, potentially significantly alter the quality of natural waters, and changes the water use potentially. The key to sustainable water resources is, therefore, to ensure that the quality of water resources are suitable for their intended uses, while at the same allowing them to be used and developed to a certain extent (Mason, 2000). The degradation of physical and chemical water quality due to human influences is often gradual, and subtle adaptations of aquatic ecosystems to these changes may not always be readily detected until a dramatic shift in ecosystem condition occurs. For example, in many shallow European lakes, the gradual enrichment of the surface water with plant nutrients has resulted in shifts from systems that once were dominated by rooted aquatic plants to systems that are now dominate by algae suspended in the water column (Scheffer et al., 2001).

Kalwale and Savale noted that water is polluted when its accepted quality has been altered by man's activities through anthropogenic input such that its intended usage for commercial or domestic purpose is hampered (Kalwale and Savale, 2012). Oceans, lakes, rivers and streams can naturally clean up a certain amount of pollution by distributing it harmlessly (Kanu and Achi, 2011). Today, pollution of water resources have been most exploited due to increasing population, industrialization, urbanization and broad spheres of human activities. Rapid population growth rate and other factors such as agricultural activities and commercial processes have resulted in the accumulation of wastes and pollutions which end up in water bodies, thus altering the water quality, species composition and biodiversity in many aquatic systems (Leslie, 2010).

3. MATERIALS AND METHODS

3.1 Study Area

Bukuru is one of the major towns in Jos South Local Government Area, Plateau State (Figure 1) and known for mining activities. Jos South is bordered in the north by Jos North and part of Bassa Local government Areas, Plateau State, in the east by Jos East and Barkin-Ladi Local Government Areas, in the south by Riyom Local Government Area and in the west by parts of Riyom and Bassa Local Government Areas. Jos South L.G.A is located within latitude 9^{0} 54' N to 10^{0} 43' N and longitude 08^{0} 52' E to 08^{0} 52' E as shown on Figure 1. The study area is accessible with a major road, minor and secondary roads. The study area is characterized by two major seasons: wet and dry seasons. The wet (rainy) season usually starts from the month of April and continues till mid or early October when the frequency and intensity would have drastically reduced. The rainy season is usually brought about by the South –Western Trade wind blowing from the Atlantic Ocean into the country. The dry season usually starts from the month of November to March under the influence of the North-east Trade wind which blows from the Sahara Desert into the country. The effect of the harmattan wind is severely felt during the months of December and January and characterized by very cold, dry and dusty wind. The mean monthly temperature of the area ranges between 19.93^{0}C to 27.4^{0}C. Geologically, the study area is overlain by the younger granite province in Jos-Bukuru ring complex. The younger granite province is a petrography province in Africa characterized by acid rocks which bear distinctive mineralization.

3.2 Data Collection

Five representative unreclaim ponds were selected in Bukuru town, while a control point was established in Riyom town which is a different Local Government Area, from Jos South. Riyom was chosen as a control point because it is known to have recorded the least mining activities as well as also been used as irrigation and fishing ponds (Stephen, 2007). Samples of sediment, catfish and tomato were collected in each of the five selected sampling points in Bukuru for heavy metals analysis. The selected sampling points were chosen due to accessibility, their geospatial spread across the study area and the fact that the unreclaimed pits are currently been used for irrigation and fish farming which are major sources of livelihood in the study area. At each of the sampling points, the geographical coordinate of each location was recorded with the aid of a Global Positioning System (GPS) Table 1.

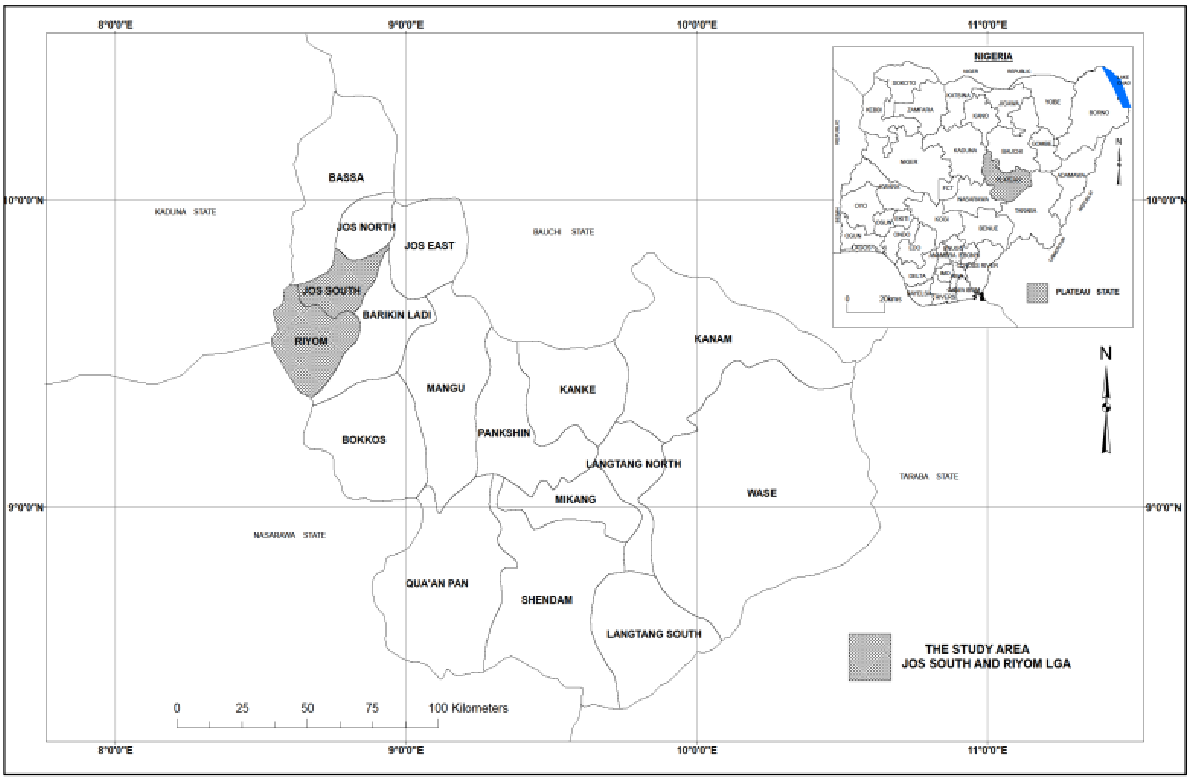

Figure 1: Jos South and Riyom Local Government Area.

Table 1: Geographical Coordinates of Sample Locations

Station	Location	Coordinate	Elevation	Altitude
BKW I	ECWA farm, Bukuru	N09048.2991 E008053.2361	1288m:	A=8.7m
BKW II	Behind ECWA farm 1, Bukuru	N09048.334 E008052.685	E=1268:	A=9.0m
BKW III	Behind ECWA farm 2, Bukuru	N09048.3421 E00852.688	E=1266:	A=8.8m
BKW IV	Behind Yelwa club junction, Bukuru	N09048.010 E008052.452	E=1271:	A=8.4
BKW V	ECWA family church, Bukuru	N09048.975 E008054.219	1289:	A= 6.9m

3.3 Sediment Sampling

Sediment samples were collected for a period of six (6) months, from January to March and July to September, representing dry and rainy seasons respectively. A total of 32 sediment samples were collected for the study, 15 samples in each of the seasons across the five-sampling point, and a control sample. Samples were analyzed for eight (8) heavy metals such as cadmium, manganese, mercury, copper, nickel, lead, uranium and zinc. These parameters were selected due to their high toxicity rate which are known to cause various health related problems such as liver and kidney failure, cells and tissue injury etc. Sediment was chosen for the study owing to the fact sediments are considered an important indicator of chemical contamination and due to the sensitivity of soil and soil organisms to environmental stress and changes due to pollution (Egbe and

Alhunanya, 2016; Zaghloul et al., 2019; Fikret and Yalçin, 2019; Parmar et al., 2016; Ankita and Jyoti, 2020). It is also known that heavy metals are more concentrated in the bottom sediments (Mandal and Kaur, 2019; Marzena et al., 2014). The sediment samples were collected using plastic spatula by scooping top layer sediments into dried black polyethylene bags. The polyethylene bag samples were labelled with appropriate source and date of collection before being transported to the laboratory of the Kaduna State Environmental Protection Agency (KEPA) where they were oven-dried and stored for analysis.

3.4 Collection of Catfish Samples

Catfish samples were collected during the period for which sediment data was collected from January to March and July to September, representing dry and rainy seasons respectively. A total of eight (8) fish samples were collected with 3 samples in each of the seasons in addition to two (2) control samples for rainy and dry season. The samples were analyzed for 8 heavy metals which includes cadmium, manganese, mercury, copper, nickel, lead, uranium, and zinc. Catfish was chosen because research has shown that Fish is considered a good bio-assay indicator for the aquatic pollution because of their sensitivity to changes in the aquatic ecosystem (Daoud et al., 2020). More so, Catfish is a major source of protein for the community and source of livelihood in the study area and beyond. The fish samples were collected using fishhooks and or fish nets and kept in black polyethylene bags. The polyethylene bag samples were labelled with appropriate source and date of collection before being sun-dried and transported to the laboratory of the Kaduna State Environmental Protection Agency (KEPA) for analysis.

3.5 Collection of Tomato Samples

Tomato samples were collected the period for which sediment data was collected from January to March and July to September, representing dry and rainy seasons respectively. A total of eight (6) tomato samples were collected with 3 samples in each of the seasons in addition to two (2) control samples for rainy and dry season. The samples were analyzed for 8 heavy metals which includes cadmium, manganese, mercury, copper, nickel, lead, uranium, and zinc as the case with water. Tomato fruit was chosen as research has shown that vegetables are a good bio-assay indicator for aquatic pollution (Marzena et al., 2014; Mandal and Kaur, 2019). More so, tomato fruit is a major source of livelihood for the populace in the study area and beyond. Tomato samples were handpicked and stored in black polyethylene bags. The polyethylene bag samples were labelled with appropriate source and date of collection before being sun-dried and transported to the laboratory of the Kaduna State Environmental Protection Agency (KEPA) for analysis.

3.6 Sample Preparation

Preparation of Sediment Sample: - The sediment samples were oven-dried (to avoid microbial effects), crushed and passed through a 2mm sieve and subjected to laboratory analyses using standard procedures. About 2.0g portion of dried sediment (representing one-third of the total weight) were digested in 15cm^3 of tri-acid mixture (HNO_3, HCI and H_2SO_4 at 5:1:1 ration) at 80^{0}C until a transparent solution appeared. After cooling, the digested samples were filtered using what man No.41 filter paper and the filtrate was finally maintained at 50 cm^3 distilled water. The clear solution was then poured into sample bottles for reading in the Atomic Absorption Spectrometer (Marzena et al., 2014; Mandal and Kaur, 2019).

Preparation of Catfish sample (Digestion): - The fish samples were oven-dried (to avoid microbial effects), crushed and passed through a 2mm sieve and subjected to laboratory analyses using standard procedures. About 2.0g portion of dried fish (representing one-third of the total weight) were digested in 15cm^3 of tri-acid mixture (HNO_3, HCI and H_2SO_4, as 5:1:1 ration) 80^{0}C until the transparent solution appeared. After cooling, the digested samples were filtered using what man No.41 filter paper and the filtrates were finally maintained at 50 cm^3 distilled water. The clear solutions were then poured into sample bottles for reading in the Atomic Absorption Spectrometer.

Preparation of plant sample (Digestion): - Tomato samples were oven-dried (to avoid microbial effects), crushed and passed through a 2mm sieve and subjected to laboratory analyses using standard procedures. About 2.0g portion of dried plants (representing one-third of the total weight) were digested in 15cm^3 of tri-acid mixture (HNO_3, HCI and H_2SO_4 at 5:1:1 ration) 80^{0}C until the transparent solution appeared. After cooling, the digested samples were filtered using what man No.41 filter paper and the filtrates were finally maintained at 50 cm^3 distilled water. The clear solutions were then poured into sample bottles for reading in the Atomic Absorption Spectrometer (Marzena et al., 2014; Mandal and Kaur, 2019).

3.7 Preparation of Standard Curve

The standard curves for the heavy metals were prepared bearing in mind that these elements occur in trace concentration. Standard solutions will be prepared from 1000 parts per millions (ppm) stock solution. 1ml of the 1000ppm stock solution was pipetted into a 100ml volumetric flask and made up with distilled water. This solution was 10ppm of the solution. From this solution, standard solutions of 0.2, 0.4, 0.6, 0.8 and 1ppm will be prepared by taken 0.2, 0.4, 0.6, 0.8 and 1ml portions into 10ml volumetric flasks and made to mark. These were then run in the Air Acetylene flame and standard curves for the various elements were obtained.

3.8 Analytical Method

The analysis of the selected heavy metals were carried out using Atomic Absorption Spectrometer (AAS) (Bulk Scientific Model 200H AAS) after digestion of the sample at the Kaduna State Environmental Protection Agency (KEPA), Kaduna. This method is suitable for both dissolved and total metals in soil. 100ml of the digest in each sample was run on the Atomic Absorption Spectrometer (AAS) which uses Air Acetylene Flame. By choosing the correct wavelength of the various elements and running a known standard curve of the various elements, the absorbance of the chemical elements present in the samples were determined. Using the standard absorbance of the various elements, the absorbance from the various heavy metals contained in the samples was converted to parts per million (ppm) or milligram per liter (mg/l) values as their levels of concentration (Marzena et al., 2014; Mandal and Kaur, 2019).

3.9 Statistical Analysis

The results obtained from the laboratory analysis are subjected to simple descriptive statistics each as mean, and standard deviation (SD). The student t test at 0.05 significant levels was used to carry out comparison sample distributions. The t-test is chosen because the study made use of mean, the study is comparing the means of two sample sets that is seasonal variability. The statistical analysis is conducted using Microsoft Excel and SPSS (version 16.0) statistical package.

4. RESULTS AND DISCUSSION

In Table 2 and 3, the results of rainy season concentrations of heavy metals in surface sediment from unreclaimed mining pits used for irrigation in Bukuru, Jos south are presented. All the heavy metal parameters except Zn, exceeded levels observed at control point as well as maximum permissible limits in the rainy season. Near similar pattern was also observed in the dry season distribution with few deviations from one sampling point to another. For example, Cd level was within maximum permissible limits in BKSI (ECWA farm, Bukuru). Ni level was within maximum permissible limit at BKSI (Behind ECWA farm 1), BKSII (Behind ECWA farm 2, Bukuru) and BKSIII, while at BKS1 (ECWA farm, Bukuru), Pb level was within maximum permissible limit. Zinc levels were generally high in all the seasons though within the maximum permissible limit for human consumption as well as below the levels observed at control point. In Table 4, compared mean concentration of heavy metal in sediment across sampling points is presented.

Mean concentration of Cd across sampling points were 0.13 and 0.09 in rainy and dry season respectively. Statistical difference was not established in concentration levels across the sampling stations between rainy and dry season at $\rho > 0.05$, d = 0.10. The percentage of deviation between the two seasons was 18.2%. Mean concentration of Mn across the sampling points were 1.20 and 1.466 in rainy and dry seasons respectively. Although dry season mean was higher that level in rainy season, statistical difference was established between the two seasons at $\rho < 0.05$, d = 0.22. Percentage of deviation between the two seasons was 9.97%. Mean levels of Hg across the sampling points were 0.03 and 0.02 in rainy and dry season respectively, while percentage of deviation was 20.0%. Statistical difference was not observed in the concentration levels across the sampling points at $\rho > 0.05$, d = 0.23.

Mean levels of Cu for rainy and dry seasons were 1.85 and 2.25 respectively. Percentage deviation from mean level was 9.75%, while statistical difference was not established between the concentration levels across the sampling points at $\rho > 0.05$, d = 0.25. Mean level of Ni across the sampling points were 0.65 and 0.68 for rainy and dry season respectively. Statistical differences were not observed at $\rho > 0.05$, d = 0.18, while percentage of deviation from mean was 2.25%. Mean levels of Pb across the sampling points were 0.11 and 0.10 for rainy and dry seasons respectively. Differences in the concentration level across the sampling points was not statistically significant at $\rho > 0.05$, d = 0.46. The percentage deviation in mean concentration between the two seasons was 4.7%.

Mean levels of Ur for rainy and dry seasons were 0.92 and 1.88 respectively. Percentage deviation from mean level was 34.3%, while statistical difference was not established between the concentration levels across the sampling points at $\rho > 0.05$, d = 0.12. Across sampling points, mean levels of Zn were 1.81 and 1.91 for rainy and dry seasons respectively. Statistical difference was not established in levels Zn across sampling stations at $\rho > 0.05$, d = 0.39. The percentage of deviation in mean levels of Zn across the sampling point was 2.7%. Overall, concentration levels of investigated heavy metals in sediment samples across the sampled points did not differ significantly between seasons. More so, Cd, Hg, and Pb were slightly higher during the rainy season, while Mn, Cu, Ni, Ur and Zn levels were higher in the dry season when compared to levels seen in rainy season.

In Figures 2 and 3, comparison of mean seasonal levels of heavy metal in sediment samples with control, showed statistical difference in concentration levels between mean concentration and pattern observed at control point at $\rho < 0.05$, d = 0.007. Similar pattern was observed for the dry season at $\rho > 0.05$, d = 0.008, an indication that the level of heavy metals presence in sediment samples from unreclaimed mining pits is statistically higher than levels at control point, irrespective of season. This is expected especially as sediments are known to be good reservoirs for heavy metals accumulation over a period irrespective of dilution from rainwater.

Table 2: Rainy Season Concentration of Heavy Metal in Sediment from Unreclaimed Mining Pits Used as Fishponds Bukuru, Jos South

		BKS I	BKS II	BKS III	BKS IV	BKS V	Control	NESREA Standard
Cd (mg/l)	Mean Conc. Level (6 months)	0.0916	0.1236	0.216	0.1211	0.0819	0.0075	<01
Mn (mg/l)	Mean Conc. Level (6 months)	0.817	1.711	1.4666	1.031	0.956	0.0018	<01
Hg (mg/l)	Mean Conc. Level (6 months)	0.061	0.0173	0.0167	0.0212	0.013	0.0001	<0.0001
Cu (mg/l)	Mean Conc. Level (6 months)	1.6881	2.0421	1.816	2.1134	1.5667	0.0118	>02
Ni (mg/l)	Mean Conc. Level (6 months)	0.1426	0.0857	0.7	1.315	1.0244	0.011	<0.59
Pb (mg/l)	Mean Conc. Level (6 months)	0.0631	0.076	0.0598	0.1636	0.166	0.02	<01
Ur (mg/l)	Mean Conc. Level (6 months)	0.25	1.6	1.07	0.45	1.22	-	<0.003
Zn (mg/l)	Mean Conc. Level (6 months)	1.876	2.0111	1.5023	2.251	1.4284	0.0674	3

Table 3: Dry Season Concentration of Heavy Metal in Sediment from Unreclaimed Mining Pits Used as Fishponds Bukuru, Jos South

		BKS I	BKS II	BKS III	BKS IV	BKS V	Control	NESREA Standard
Cd (mg/l)	Mean Conc. Level (6 months)	0.0076	0.0876	0.1026	0.1416	0.095	0.0075	<01
Mn (mg/l)	Mean Conc. Level (6 months)	0.4594	1.37	1.4626	2.0717	1.966	0.0018	<01
Hg (mg/l)	Mean Conc. Level (6 months)	<0.0001	0.012	0.0176	0.0237	0.0237	0.0001	<0.0001
Cu (mg/l)	Mean Conc. Level (6 months)	0.1072	2.107	2.714	3.1701	3.1701	0.0118	<01
Ni (mg/l)	Mean Conc. Level (6 months)	<0.0001	0.216	0.2461	1.1266	1.1266	0.011	<0.5
Pb (mg/l)	Mean Conc. Level (6 months)	0.001	0.0548	0.0644	0.2	0.2	0.02	<01
Ur (mg/l)	Mean Conc. Level (6 months)	-	1.01	2.5	2.01	2.01	-	0.023
Zn (mg/l)	Mean Conc. Level (6 months)	0.8172	1.8116	2.0781	2.4187	2.4187	0.0674	3

Table 4: Student T-Test Comparison of Mean in Heavy Metal Levels in Sediments Between Seasons From Unreclaimed Mining Pits Used as Fishponds Bukuru, Jos South

		BKS I	**BKS II**	**BKS III**	**BKS IV**	**BKS V**	**Mean±SD**	**P-value**	**% of Deviation**
Cd (mg/l)	Rainy	0.0916	0.1236	0.216	0.1211	0.0819	0.13 ± 0.05	0.10	18.2
	Dry	0.0076	0.0876	0.1026	0.1416	0.095	0.09 ±0.05		
Mn (mg/l)	Rainy	0.817	1.711	1.4666	1.031	0.956	1.20± 0.38	0.22	9.97
	Dry	0.4594	1.37	1.4626	2.0717	1.966	1.466±0.64		
Hg(mg/l)	Rainy	0.061	0.0173	0.0167	0.0212	0.013	0.03 ± 0.02	0.23	20.0
	Dry	<0.0001	0.012	0.0176	0.0237	0.0237	0.02±0.01		
Cu (mg/l)	Rainy	1.6881	2.0421	1.816	2.1134	1.5667	1.85±0.23	0.25	9.75
	Dry	0.1072	2.107	2.714	3.1701	3.1701	2.25±1.27		
Ni (mg/l)	Rainy	0.1426	0.0857	0.7	1.315	1.0244	0.65±0.54	0.18	2.25
	Dry	<0.0001	0.216	0.2461	1.1266	1.1266	0.68±0.54		
Pb(mg/l)	Rainy	0.0631	0.076	0.0598	0.1636	0.166	0.11±0.05	0.46	4.7
	Dry	0.001	0.0548	0.0644	0.2	0.2	0.10±0.09		
Ur (mg/l)	Rainy	0.25	1.6	1.07	0.45	1.22	0.92±0.56	0.12	34.3
	Dry	-	1.01	2.5	2.01	2.01	1.88±1.00		
Zn(mg/l)	Rainy	1.876	2.0111	1.5023	2.251	1.4284	1.81±0.35	0.39	2.7
	Dry	0.8172	1.8116	2.0781	2.4187	2.4187	1.91±0.66		

Note: Difference is statistically significant at 0.05 level of confidence (one-tail)

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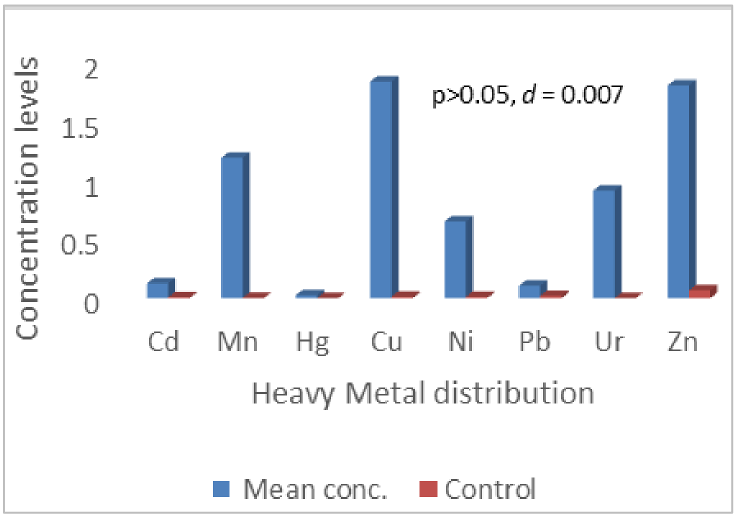

Figure 2: Compared Rainy season levels of heavy metal in sediment from unreclaimed mining pits used as fishponds Bukuru, Jos south and control point (Riyom)

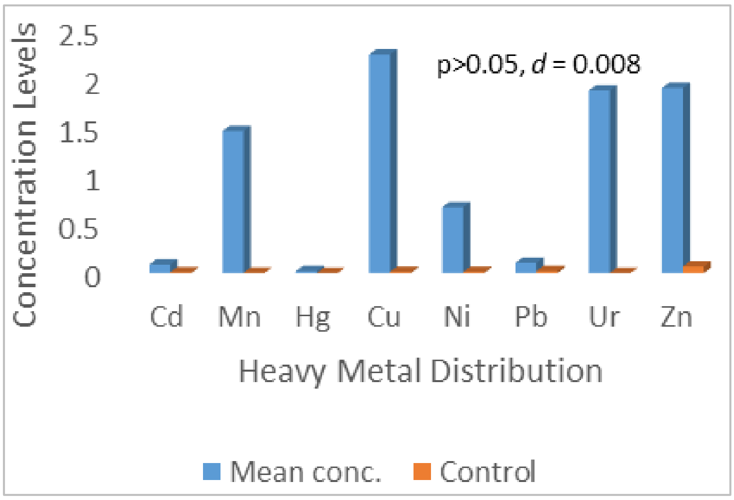

Figure 3: Compared Dry season levels of heavy metal in sediment from unreclaimed mining pits used as fishponds Bukuru, Jos south and control point (Riyom)

Mean seasonal distributions of heavy metals in catfish and tomato fruit are presented in Table 5 and 6. In rainy season, Cd, Mn, Cu, Pb and Zn exceeded observed levels observed with control sample as well as maximum permissible limit for fish consumption. Cd, Mn and Zn were also above maximum permissible limit for fish consumption in dry season (Table 5). In Table 6, all the heavy metals investigated except Hg and Ur which were not detected exceeded the maximum permissible limit for tomato consumption for both seasons.

Table 5: Seasonal Concentration of Heavy Metal in Catfish (Siluriformes) From Unreclaimed Mining Pits Used as Fishponds Bukuru, Jos South

	Rainy Season	**Rainy season Control**	**Dry Season**	**Dry season Control**	**NESREA STANDARD**
Cd	0.012	0.01	0.014	0.11	0.01
Mn	0.012	0.0021	0.122	0.22	0.03
Hg	-	0	0.0001	0.0001	<0.0001
Cu	0.112	0.005	0.108	0.25	1
Ni	0.001	0.0017	0.011	0.01	0.02
Pb	0.011	0.0001	0.001	0.02	0.05
Ur	-	-	-	-	-
Zn	0.241	0.0067	0.231	0.08	1.0

Table 6: Seasonal Distribution of Heavy Metal in Tomato (Lycopersium Escalentum) from Unreclaimed Mining Pits Used for Irrigation in Bukuru, Jos South

	Rainy Season	Rainy season Control	Dry Season	Dry season Control	NESREA STANDARD
Cd	0.0123	0.0001	0.0217	0.00129	<01
Mn	0.1245	0.00016	0.388	0.0145	<01
Hg	-	0.0001	0.0001	-	<0.0001
Cu	1.1129	0.0074	1.514	0.0192	<01
Ni	0.0012	0.0036	0.002	0.0024	<0.59
Pb	0.001	<0.0001	0.003	0.00192	<01
Ur	-	-	-	-	<3
Zn	0.8451	0.0175	1.241	0.459	3

In Table 7 compared seasonal distributions of heavy metals between sediment sample and catfish sample as well as between control samples (fish) are presented. In rainy, statistical difference was observed in heavy metal levels between sediment and catfish sample at $\rho < 0.05$, d = 0.006. In the dry season, the pattern was also similar at $\rho < 0.05$, d = 0.02. These results are indication of very slow rate of bioaccumulation of heavy metals in catfish from heavy metal contaminated sediment. This could also suggest difference in the timing of absorption of heavy metals in sediment and subsequence intake and bioaccumulation in fish. The effect of dilution from rainwater may also play to decrease the heavy metal intake level by fish. Although the test revealed statistically significant difference, the presence of heavy metals in fish sample, when compared to mfaximum permissible limits, shows bioaccumulation, though the rate might be slow in rainy season.

Compared levels of heavy metal levels between fish samples from the unreclaimed mining ponds and sample from control point (Riyom) shows that the difference in concentration levels is not statistically significant at $\rho > 0.05$, d = 0.09 and $\rho > 0.05$, d = 0.23 in rainy and dry season respectively. This might be suggesting contamination at control point, Riyom which is a different local government area and is known to have recorded the least mining activities in in Jos south.

Table 7: Compared Mean Seasonal Levels of Heavy Metals Between Sediment and Fish Samples From Unreclaimed Mining Pits Used as Fishponds Bukuru, Jos South

		Cd	Mn	Hg	Cu	Ni	Pb	Ur	Zn	P-value
Rainy season	Sediment sample	0.13	1.20	0.03	1.85	0.65	0.11	0.92	1.81	0.0067
	Fish sample	0.012	0.012	-	0.112	0.001	0.011	-	0.241	
Dry season	Sediment sample	0.09	1.47	0.02	2.25	0.68	0.10	1.88	1.91	0.02
	Fish sample	0.014	0.122	0.000	0.108	0.011	0.001	-	0.231	
Rainy season sample and control	Fish sample	0.012	0.012	-	0.112	0.001	0.011	-	0.241	0.09
	control sample	0.01	0.0021	-	0.005	0.0017	0.0001	-	0.0067	
Dry season sample and control	Fish Sample	0.014	0.122	0.000	0.108	0.011	0.001	-	0.231	0.23
	Control Sample	0.11	0.22	0.0001	0.25	0.01	0.02	-	0.08	

Note: Difference is statistically significant at 0.05 level of confidence (one-tail)

Table 8: Compared Mean Seasonal Levels of Heavy Metals Between Sediments and Tomato Samples from Unreclaimed Mining Pits Used for Irrigation in Bukuru, Jos South

		Cd	Mn	Hg	Cu	Ni	Pb	Ur	Zn	P-value
Rainy season	Sediment sample	0.13	1.20	0.03	1.85	0.65	0.11	0.92	1.81	0.003
	Tomato sample	0.0123	0.1245	-	1.1129	0.0012	0.001	-	0.8451	
Dry season	Sediment sample	0.09	1.47	0.02	2.25	0.68	0.10	1.88	1.91	0.04
	Tomato sample	0.0217	0.388	0.0001	1.514	0.002	0.003	-	1.241	
Rainy season sample and control	Tomato sample	0.0123	0.1245	-	1.1129	0.0012	0.001	-	0.8451	0.07
	Control	0.0001	0.0002	0.0001	0.0074	0.0036	<0.0001	-	0.0175	
Dry season sample and control	Tomato sample	0.0217	0.388	0.0001	1.514	0.002	0.003	-	1.241	0.063
	Control	0.00129	0.0145	-	0.0192	0.0024	0.00192	-	0.459	

Note: Difference is statistically significant at 0.05 level of confidence (one-tail)

In Table 8 compared seasonal distributions of heavy metals between sediment sample and tomato sample as well as between control samples (tomatoes) are presented. In rainy, statistical difference was observed in heavy metal levels between sediment and tomato sample at $\rho < 0.05$, d = 0.003. In the dry season, the statistical difference was marginal at $\rho < 0.05$, d = 0.04. Like pattern observed for catfish, these results are indication of very slow rate of bioaccumulation of heavy metals in tomatoes from heavy metal contaminated sediment. This could also suggest difference in the timing of absorption of heavy metals in sediment and subsequence intake and bioaccumulation in tomatoes. The effect of dilution from rainwater may also play to decrease the heavy metal intake level by tomatoes.

Although the test revealed statistically significant difference, the presence of heavy metals in tomatoes sample, when compared to maximum permissible limits, shows bioaccumulation, though the rate might be slow especially in rainy season. Compared levels of heavy metal levels between tomato sample from the unreclaimed mining pit and sample from control point shows that the difference in concentration levels is not statistically significant at $\rho > 0.05$, d = 0.07 and $\rho > 0.05$, d = 0.063 in rainy and dry season respectively. The fact that heavy metal levels in tomatoes samples from the unreclaimed mining pits did not differ from samples collected from the control points may also suggest contamination at control point, Riyom which is a different local government area and is known to have recorded the least mining activities in in Jos south.

5. Conclusion

The results from the study clearly reveal the high concentrations of heavy metals in tomatoes, catfish and soil samples collected from the unreclaimed mining field. Dry season samples show reasonable statistical difference in concentrations exceeding acceptable limits in tomatoes, catfish and sediments. There are severe consequences for consumption of fruits and vegetables cultivated in such locations as they bioaccumulate and cause kidney and liver failures. There is therefore the need to reclaim all previously abandoned mining sites using recommended standard engineering procedures to advert epidemics.

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