Accumulated Potentially Toxic Metals in Soil, Irrigation Water, and Edible Part of Selected Vegetables Along Dambo Dam, Jigawa State Nigeria

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ABSTRACT: *Even though heavy metals are important plant nutrients when grown on contaminated soil or irrigated with polluted water, plants accumulate high levels of heavy metals and if consumed, negative health consequences occur. In this study, the accumulated potentially toxic metals in the edible part of selected vegetables, soil, and irrigation water along the Dambo Dam of Jigawa state, Nigeria were assessed using the AAS method. Additionally, the translocation factor, the Monomial Ecological Risk (E_r^i), and the potential ecological risk index of these potentially toxic metals on the selected vegetables were evaluated. The result revealed that the concentrations of these potentially toxic metals in water, soil, and vegetables are in the order Mn>Pb>Zn>Ni>Cd>Cu, except for lettuce where Pb was found to be higher than Mn. Furthermore, the concentrations of Zn, Mn, Cd, Pb, Cu, and Ni were all within the permissible limits set by World Health Organization. All the samples analyzed contained high levels of these metals, indicating evidence of contamination, which may be due to anthropogenic activity. The monomial ecological Risk (E_r^i) of these metals in lettuce is in the order; Cd > Pb > Ni > Zn > Mn. While for cabbage, the order is Cd > Ni > Pb > Zn > Mn. The E_r^i of Zn and Mn are within the Low-Risk values of $E_r^i < 40$, and that of Cd is the range of $160 \le E_r^i < 320$, considered very high, in both lettuce and cabbage. Whereas, Ni and Pb in cabbage are within $40 \le E_r^i < 80$, considered a Moderate Risk. The highest Potential Ecological Risk Index (RI) was observed to be 400.24 in cabbage and 284.55 in lettuce, which is deemed very dangerous, as it is above the range of $200 \le RI < 400$.*

KEYWORDS: *Edible Plants; Potentially Toxic Metals; AAS analysis; Bioaccumulation; Risk Index.*

INTRODUCTION

Heavy metals (a potentially toxic metal) are highly toxic because of their non-biodegradable nature and bioaccumulation in the human body [1]. These metals are called “heavy metals” (HM) since in their standard state

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1021-9986/2022/10/3667-3678 12/$/6.02

they have a specific gravity greater than 5 g/cm^3 [2]. The HM accumulates in soils and plants over time and can have a detrimental impact on plant physiological activities such as photosynthesis, gaseous exchange, and nutrient absorption. In small concentrations, some heavy metals are non-toxic, however, cadmium and mercury are exceptions as they are toxic to plants or animals even in very low concentrations [3]. Heavy metals contamination is becoming more rapid in urban areas mostly due to the disposal of domestic wastes into rivers and dams [4].

Vegetables are an important ingredient of the human diet as they contain essential nutrients and trace metals that are biologically important but could be toxic if the trace metals are above the recommended level [5]. Vegetables cultivated on soil contaminated with heavy metals are found to contain these metals stored in their tissues, causing detrimental health problems, including metabolic abnormalities in people who eat the vegetables since the body lacks a system to remove heavy metals [6]. Consumption of these vegetables as well as the animals that feed on the vegetables has been a major food chain route for human exposure to heavy metals [7]. *Sultana* [8] reported that, high level of Cd results in a higher risk of cancer.

Point source pollutants from mines and many sectors, as well as water drainage from natural environments, are the primary sources of heavy metal contamination in water [9]. There is an average of 20% of chromium, 8% of nickel, 1.6% of lead, 0.05% of mercury, and 0.02% of cadmium in a "natural soil" [10]. The detrimental impact of heavy metals on land, surface water, plants, and animals, as well as humans, makes it essential to monitor the level of contamination [11,12].

Many types of research have been conducted to explain heavy metal bioaccumulation in soils and plants. Based on their findings, several scholars have recommended that heavy/potentially toxic metals be monitored daily since the absorption of these Potentially toxic metals by plants varies greatly depending on the type of plant [13]. According to *Kim et al.* [14], the Transfer Factor (TF) of heavy metals from soil to plant is important because it is a factor that quantifies heavy metal bioavailability in agricultural products. In this study, concentrations of As, Cd, and Pb measured in eight agricultural products (rice, barley, corn, pulses, pumpkin, apple, pear, and tangerine) and soil revealed an average of 0.006-0.309 (As), 0.002-6.185 (Cd), 0.003-0.602 (Pb) for both plants and soil. It was also found that the maximum mean TF value of As was 0.309 in Rice, 6.185 in lettuce, and 0.717 in pear; that of Cd was 0.308 in rice, 0.602 in lettuce; while for Pb in pumpkin, it was 0.536. This indicated that the variability depends on the vegetable species.

In a related study, the concentrations of Lead (Pb), Cadmium (Cd), Iron (Fe), Zinc (Zn), and Copper (Cu) determined in four separate samples of vegetables obtained from the central market, Katsina, revealed that the mean concentration of metals ranged from 0.071 mg/kg Pb to 0.632 mg/kg Cu, and the relative abundance of these metals in vegetables was Cu (0.483 mg/kg) > Zn (0.268 mg/kg) > Fe (0.260 mg/kg) > Pb (0.095 mg/kg), these values are far below the FAO/WHO prescribed metals thresholds in vegetables [15].

OlabimpeIyabo et al. [16], established that metals as environmental contaminants in domestic dumpsites, can be swept up and transported by runoff water and end up in rivers, lakes, and even absorbed by plants, resulting in concentrations above the regulatory bodies' recommended levels. According to his study on heavy metals in the soil of major domestic dumpsites in Akure township, the concentrations of Zn, Fe, Cu, Pb, Cd, Ni, and Cr in µg/g ranged from 360.00-441.00, 169.60-547.20, 37.20-102.00, 18.80-80.00, 2.36-2.95, 11.00-19.20, and 18.00-42.20, respectively.

In another study carried out in Bangladesh adjacent to a multi-industry district, heavy metal concentrations in vegetables were assessed and were found to surpass the permissible thresholds in both wet and dry seasons. However, the metal concentrations in soil were below permissible thresholds, with Zn having the highest concentration and Cd with the lowest concentration in irrigation water, soil, and vegetables. The heavy metal concentrations were observed to be lower in the wet season compared to the dry season. This was attributed to rainfall dilution, low heavy metal absorption from diluted irrigation water, and heavy metal absorption from low concentrated irrigation water and/or soil [17].

In line with the highlighted problem, it is imperative to assess the level of heavy metals in irrigation water, agricultural soils, and vegetables grown in the area to determine the variability in concentration level and translocation of the heavy metals. For this reason, the present research assessed the concentration level of some potentially toxic metals (Pb, Mn, Ni, Zn, Cd, and Cu) in irrigation water, soil, and selected vegetables (cabbage and lettuce) from farms along Dambo Dam, Jigawa State Nigeria. In addition, the uptake (translocation factor) of these potentially toxic metals by the vegetables from the water and soil of the irrigation areas were investigated, and the Monomial Ecological Risk (E_r^i) of each single potentially toxic metal in cabbage and lettuce samples computed. Furthermore, the potential ecological risk index of these potentially toxic metals on the selected vegetables was evaluated. The fact that Dambo Dam is surrounded by hills and domestic waste plus the waste from landfills, that likely to contain heavy metals, are used as manure for the local farming practice among the environs, prompted the present study.

EXPERIMENTAL SECTION

Description of Study Area

Dambo dam as depicted in Fig. 1, is located in Maradawa village along Kazaure-Roni Road of Jigawa State, it falls between *12°.39'23.0” N, 8°.22'45.0" E* to *12°.38'13.7” N 8°.21'51.1" E* on the globe. It is surrounded by hills and highlands. Run-off water from different point dissolves and pick up different mineral both essential and toxic and deposits into the dam.

Materials

Agilent Technologist 200 series Atomic Absorption Spectroscopy 240FS, Garmin GPS 60^{TM} Personal Navigator, Mi105 Martini Professional portable pH/temperature meter, Hot plate, Analytical weighing balance, Whatman 42 filter paper, Scoop and Fabricated Vendor sampler

Reagent

All reagents are of analytical grade and used without further purification. 65% HNO_3, 37% HCl, and 72% HClO were purchased from QRëC^{TM}. Lead Nitrate, Zinc Oxide, Anhydrous Cadmium Chloride, Copper Nitrate Tri-Hydrate, Nickel Nitrate Hexa-Hydrate, and Manganite Chloride Tetra-Hydrate were purchased from Sigma.

Plant, soil, and water sampling

The choice of vegetable samples was mainly based on their availability and frequency in daily consumption. Leaves of Cabbage and Lettuce samples were collected from Dambo Dam, using stratified sampling techniques, and were stored in a freezer. For each vegetable sampled, the surrounding soil was collected using Scoop as described in [18]. The coordinate location of each sampling site was read and recorded using the Garmin GPS 60^{TM} Personal Navigator site for December, January, February, and March as indicated in Tables 1 and 2. The soil samples were dry in an oven at 40 ºC for 24 h, ground with a pestle and motor, and sieved. A representative sample was obtained by coning and quartering techniques as described in [19].

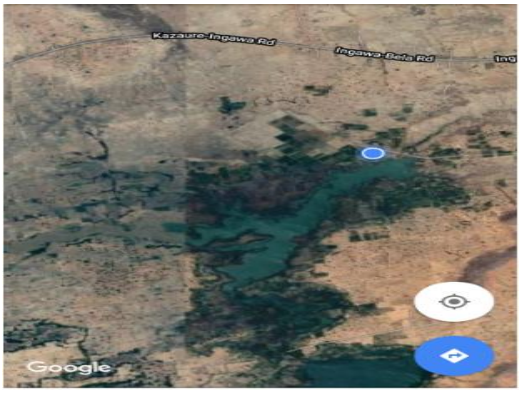

Fig. 1: Map of Kazaure local government (key: D= Dambo Dam).

The water samples were collected at the depths of 0.5 m, 1.0 m, and 1.5 m using a modified Van Dorn sampler, and the temperature and pH were recorded immediately. The water samples were filtered through Whatman No 42 filter paper, transferred into an amber-colored polyethylene bottle, and acidified with HNO_3 acid to stabilize the metals before being transported to the laboratory. The samples were stored in a refrigerator at 4 °C as described in [19].

The vegetable samples were washed with distilled water and allowed to drain at room temperature. Then, the edible parts were chopped, dried in a hot air oven at 60 °C for 48 h, and ground into powder using a pestle and motor as described in [20]. The sample was stored in polythene bags for further analysis.

Digestion method

The Vegetables, soil, and water samples were digested using a freshly prepared a*qua regia*. The aqua regia was prepared by mixing 2 mL 65% HNO_3 and 6 mL 37% HCl (i.e. 1:3 ratio of HNO_3 to HCl) as described in [21, 22].

Table 1: Sampled location and GPS reading (coordinate) for water collected at Dambo Dam.

S/N	Water Sample ID	Depth(m)	Longitude and Latitude
A	D_{W1}, D_{W4}, D_{W7}, and D_{W10}	0.5	Long: N12^{o}3917.1'
			Lat:E008^{o}22.529'
B	D_{W2}, D_{W4}, D_{W8}, and D_{W11}	1.0	Long: N12 ^{o}39.171'
			Lat:E008^{o} 22.529'
C	D_{W3}, D_{W4}, D_{W9}, and D_{W12}	1.5	Long: N12^{o} 39.171'
			Lat:E008^{o} 22.529'

Key: D_{W1}, D_{W4}, D_{W7}, and D_{W10}, stands for the Dambo water, collected from a depth of 0.5 M, D_{W2}, D_{W4}, D_{W8}, and D_{W11} Dambo water collected from a depth of 1.0 M and D_{W3}, D_{W4}, D_{W9}, and D_{W12} Dambo water collected from a depth of 1.5 M between December to march respectively while the Alphabet (A, B, C) indicate the sampling site respectively.

Table 2: Sampled location and GPS reading (coordinates) for the Soil, Cabbage, and Lettuce.

S/N	Sample I.D			Longitude and Latitude
	Soil	Cabbage	Lettuce	
A	D_{S1},D_{S4},D_{S7} and D_{S10}	D_{C1},D_{C4},D_{C7} and D_{C10}	D_{L1},D_{L4},D_{L7} and D_{L10}	Lat: E008^{o}22.452’
				Long: N12^{o}39.219’
B	D_{S2},D_{S4},D_{S8} and D_{S11}	D_{C2},D_{C4},D_{C8} and D_{C11}	D_{L2},D_{L4},D_{L8} and D_{L11}	Lat: E008^{o}22.449’
				Long: N12^{o}39.212’
C	D_{S3},D_{S4},D_{S9} and D_{S12}	D_{C3},D_{C4},D_{C9} and D_{C12}	D_{L3},D_{L4},D_{L9} and D_{L12}	Lat: E008^{o}22.456’
				Long: N12^{o}39.206’

Key: (D_S, D_C, D_L)are the soil sample, Cabbage sample, and Lettuce sample collected from Dambo Dam while the Alphabet (A, B, C) and numeric subscript indicate the sampling site and months(from December to March) respectively.

Digestion of vegetable samples

The vegetable samples were digested by weighing 1 g each of the dried powdered Cabbage and Lettuce samples, respectively, into a porcelains crucible, and ashed in a muffle furnace at a temperature of 550 ^{o}C for 2 h. The ashed samples were transferred into a separate 100 mL digestion tube and 9 mL of freshly prepared *aqua regia* was added, and the volume was made up to 50 mL with distilled water. The mixture was allowed to boil gently over a hot plate at 120 ^{o}C until close to dryness. It was then cooled, filtered with What Mann No. 42 filter paper, and diluted to 50 mL as described in [22].

Digestion of soil samples

The soil samples were digested by weighing 1 g of the samples into 250 mL beakers and adding 20 mL of the freshly prepared *aqua regia*. The mixture was allowed to boil gently over a hot plate in a fume hood chamber with the periodic addition of 10 mL of concentrated nitric acid until the production of red nitrous oxide (NO_2) ceased. It was then allowed to cool and 4 mL of 70-72% perchloric acid ($HClO_4$) was added and heated until a clear solution was obtained. After cooling, the solution was filtered through Whatman No. 42 filter paper and diluted to 50 mL.

Digestion of water samples

50 mL of the water samples were measured into a separate 100 mL digestion tube and 9 mL of freshly prepared *aqua regia* were added. The mixture was allowed to boil gently over a hot plate until the volume was reduced to 20 mL. To this solution, 5 mL of HNO_3 was then added and the boiling continued until a clear solution was obtained. The samples were filtered with Whatman No. 42 filter paper and the volume was made to 50 mL.

AAS analysis

The metals (Pb, Mn, Ni, Zn, Cd, and Cu) in the digested aliquot of the samples and control were analyzed using

Agilent Technologist 200 series Atomic Absorption Spectroscopy 240FS. The concentrations of the various metals in the water, soil, and vegetable samples were calculated using the expression in Eqs (1) and (2).

Preparation of standards for the AAS Analysis

Standard stock solutions (1000 mg/L) were prepared from Agilent technologies metal compounds of Zinc, Manganese, cadmium, lead, copper, and Nickel with high purity. Appropriate volumes of the standard stock solutions were diluted to obtain the working standard solutions of various concentrations for the calibration curves.

Metal concentration

The concentrations of the various metals (i.e. Pb, Mn, Ni, Zn, Cd, and Cu) in the digested aliquot was calculated using Eq. (1) for water sample and Eq. (2) for soil and vegetable samples, respectively.

$$\mathrm{metal(mg/L)} = \mathrm{C\ X\ V_1/V_2} \tag{1}$$

$$\mathrm{metal(mg/Kg)} = \mathrm{C\ X\ V_1/M} \tag{2}$$

Where: C is the concentration in mg/L of the metal in the final extract, V_1 is the volume of the final extract (50 mL), V_2 is the volume of the original sample in mL, and M is the mass of the original sample in grams (1 g) [23]

Determination of Transfer Factor (TF):

The transfer coefficient was calculated by dividing the concentration of heavy metals in vegetables by the total heavy metal concentration in the soil as expressed in Equation 3 [14; 24; 25].

$$\mathrm{TF\ or\ C_F^i} = \frac{\mathrm{C_{plant}}}{\mathrm{C_{soil}}} \tag{3}$$

Where: C_{plant} = metal concentration in plant tissue, mg/kg fresh weight and C_{soil} = metal concentration in soil, mg/kg dry weight.

Potential Ecological Risk Index of heavy metals

The RI was calculated using Equations 4, 5, and 6 as described in [24] follows

$$\mathrm{F_i} = \frac{\mathrm{c_n^i}}{\mathrm{C_o^i}} \tag{4}$$

$$\mathrm{E_r^i} = \mathrm{T_r^i X F_i} \tag{5}$$

$$\mathrm{RI} = \sum\nolimits_{i=1}^{n} = \mathrm{E^i_{r\,Zn+}} + \mathrm{E^i_{r\,Mn}} + \mathrm{E^i_{r\,Cu}} + \mathrm{E^i_{r\,Ni}} + \mathrm{E^i_{r\,Pb}} + \mathrm{E^i_{r\,Co}} \tag{6}$$

Where; F_i Is the single metal pollution index, c_n^i is the concentration of metal in the samples, C_o^i is the reference value for the metal, E_r^i is the monomial potentially ecological risk factor, T_r^i is the metal toxic response factor [24]. The values for each element are in the order Zn = Mn =1 <Cu = Ni = Pb = 5<Cd = 30 [39].

RESULT AND DISCUSSION

The results of the pH and temperature of the water are presented in Table 3. The temperature and pH of the water sample between December and March ranged between 22.3 °C to 26.2 °C and 6.91 to 7.73, respectively. This is in agreement with the finding of [16]. Temperature affects the amount of dissolved oxygen in water, which is essential for both aquatic life and other oxidation processes that require oxygen. While pH is a measure of acidity or alkalinity, it affects the water's consistency for maintaining aquatic life [26].

Concentration level of potentially toxic metal in soil, Vegetable, and Water in Dambo Dam

The concentrations of the potentially toxic metals (Pb, Mn, Ni, Zn, Cd, and Cu) analyzed in water, soil, and vegetables (lettuce and cabbage) samples are presented in Tables 4, 5, 6, and 7. It can be observed that the highest concentration of zinc was 0.055 mg/L and 14.23 mg/kg in the water and soil samples, respectively. The values are below the WHO-recommended allowable level of 5 mg/L for water and 50 mg/kg for soil. The highest concentration of Zn (17.70 mg/kg) for lettuce was obtained in March and that for cabbage was 11.98 mg/kg in December, while the lowest for both lettuce and cabbage was in February, with respective values of 12.36 mg/kg and 7.72 mg/kg. A similar result was reported by [27] and [28]. The Zn concentration of both the lettuce and cabbage are higher than the WHO-recommended acceptable maximum of 0.60 mg/kg for vegetables. Zinc is an essential micronutrient and a component of many enzymes and proteins, thus plants need it in a small amount. It is critical to plant growth because it is involved in a variety of processes. Though zinc deficiency and toxicity are uncommon, they harm crop growth and quality. Zinc increases the activity of digestive enzymes and aids

Table 3: pH and Temperature of the Water Samples.

Months	pH	Temp (ºC)
Dec.	7.25	24.2
Jan.	6.91	22.3
Feb.	7.73	24.1
Mar.	7.35	26.2

Key: DB = Dambo Dam

the plant's ability to survive cold temperatures by assisting in the formation of chlorophyll and certain carbohydrates, as well as the conversion of starches to sugars [29]. Auxins aid in growth control and stem elongation and zinc is required for their formation. When tissue zinc levels exceed 200 ppm, which is uncommon, zinc toxicity may occur [29].

The highest manganese concentrations in the water sample were 0.31 mg/L in December and 175.92 mg/kg for the soil sample in March, with a control concentration of 0.15 mg/L, and 29.99 mg/kg, respectively. The values obtained in water exceed 0.05 mg/L, while for soil the values are below the WHO-recommended permissible limit of 200 mg/kg. For the vegetable samples, lettuce has a higher concentration of Mn than cabbage in all four months. The control samples of the two vegetables, lettuce and cabbage have a high Mn concentration of 22.13 mg/kg. The varying concentration of this metal has been reported in East Ethiopia [30]. Manganese is a necessary component in nearly all living organisms, acting as an enzyme cofactor or a catalytic metal. Mn deficiency is uncommon in humans, although Mn poisoning symptoms such as hepatic cirrhosis, polycythemia, dystonia, and Parkinson-like symptoms may occur when exposed to high concentrations. Manganese is required in limited amounts for plant growth and reproduction, and it is as important as the other nutrients for development [31].

The Cd concentrations of 0.003 mg/L were detected in January for the water sample but not detected in the remaining months, as well as in the control. In soil samples, the highest Cd concentration of 0.16 mg/kg was detected in December. The value obtained for water exceeds the 0.001 mg/L permissible limits, while the Cd concentrations in soil are below the WHO-recommended permissible limit of 0.8 mg/kg for soil's Dutch norm. This may be attributed to the low retention of Cd by the soil. Cadmium is a potential carcinogen [32] and Cd-rich wastewaters result in serious human health problems (the "Itai-itai" disease), which was first reported in the 1970s [40]. In lettuce and cabbage, the highest Cd concentration of 0.91 mg/kg and 1.01 mg/kg was detected in December, respectively. All the results exceeded the WHO's allowable limit of 0.02 mg/kg and the Dutch norm for vegetables. The high concentration of Cd may be associated with precipitation of Cd from dust during the harmattan session, incineration of municipal waste such as plastics and nickel-cadmium batteries (deposited as solid waste), as well as application of manure mostly obtained from landfills where different salts of cadmium may be present.

The Pb concentrations in water and soil samples ranged between 0.04 to 1.14 mg/L and 3.88 to 35.72 mg/kg, with a control concentration of 0.052 mg/L and 2.40 mg/kg, respectively. All the values obtained in water exceed the WHO-recommended allowable limit of 0.005 mg/L, while the values are below 85 mg/kg for soil's Dutch norm. The possible sources of Pb could be running water from; landfills, motor garages (from lead batteries), the vast number of hills surrounding the dams, and atmospheric deposition [33].

In lettuce and cabbage, the highest Pb concentration of 30.35 mg/kg and 37.33 mg/kg was detected, respectively. These are higher than the WHO-recommended permissible maximum of 2 mg/kg. The higher concentration of Pb in cabbage indicated that it is a better accumulator of Pb than lettuce. This is also in agreement with the findings of Aktaruzzaman [24]. The high concentration of Pb above the standard limit implied pollutants caused by human activities. Lead is poisonous and is used in significant quantities in many electronic devices. It is also the main constituent of lead-acid batteries, which are widely used in automobile batteries and can end up in soil through erosion [28].

Cu concentrations of 0.13 mg/L were detected in the December water sample but not detected in the rest of the months, as well as the control sample. Whereas, in the soil sample 3.86 mg/kg of Cu was obtained only in March with a concentration of 2.40 mg/kg in the control. All the values are well below the Dutch normal acceptable maximum level of 1.00 mg/L for water and 36 mg/kg for soil [28]. Cu concentration of 1.05 mg/kg was detected in the cabbage control sample but not detected in both lettuce and cabbage samples. According to WHO standards [34], the concentrations are below the acceptable level of 10 mg/kg for plants. This may be attributed to the porous nature of the soil which is sandy, allowing huge leaching of these minerals. Copper is an important microelement for plant growth and occurs naturally in soil and air, However, human activities may cause it to accumulate above the allowable limit, and its content varies depending on soil type and contamination source [35].

From the analysis of water and soil samples, the highest concentrations of Ni are respectively 0.16 mg/L and 13.52 mg/kg both in January, with a control concentration of 0.036 mg/L and 3.32 mg/kg respectively. These values fall within the WHO allowable limit of 35 mg/kg for soil [34], but surpass the 0.05 mg/L for water. This result is in accord with the finding of *Aktaruzzaman et al.* [24]. The concentrations of Ni in both vegetables are below the WHO allowable maximum limit of 10 mg/kg in all the months, except in December and January for cabbage where it exceeds the recommended permissible limit. This indicates cabbage is a strong accumulator of Ni and can be unsafe for consumption. The high concentration can be connected to anthropogenic activities such as refuse and household waste disposal used as manure. This result is also in agreement with the work of *Hussain et al.* [10], where varying concentration of this metal was discovered in water, soil, and edible part of vegetables in District Mardan, Pakistan. Because it acts as an activator of the enzyme urease, nickel is considered an essential trace element for human, animal, and plant health. Ni is absorbed easily and rapidly by the plant [36]. Airborne particles emitted by brakes and wear from vehicle tires can contain significant amounts of Ni [35]. The proximity of the farming site to hills and the main road, in addition to other anthropogenic activities, may contribute to the high concentration of Ni [32].

Transfer Factor of the potentially toxic metals in Lettuce, cabbage, and the control sample

Plants transfer factor is an important component as an indicator of heavy metals in soil and a factor that quantifies bioavailability or influential factor on the prediction of uptake of such metals to agricultural products [14]. The transfer factors are presented in Tables 8 and 9. In December, the lettuce sample has the highest transfer factor of 5.54 for Cd. While for January, February, and March the metal with the highest transfer factor was Zn with the values of 4.58, 2.32, and 1.25, respectively. The transfer factor of the control sample was; Zn 2.19, Mn 0.74, and Ni 0.56 respectively. The result agrees with the works of *Limin* and *Changxu* [27]; *Ogundele* [28]; *David* and *Kacholi* [33]. All the values obtained in lettuce are within the low to Moderate Contamination Factor of $1 \leq C_F^i < 3$ except for Zn in January which has Considerably Contamination Factor as the value falls within $3 \leq C_F^i < 6$ standard as described in *Limin* and *Changxu* [27].

Similarly, the cabbage sample has the highest transfer factor of 6.19 for Cd in December. In January, February, and March, the metal with the highest transfer factor was Pb; 4.73, Zn; 1.45, and Cd; 0.69, respectively. This agreed with the result of David and Kacholi [33]. For the control sample, the transfer factor of Zn, Pb, Ni, and Mn are respectively 5.19, 4.35, 1.69, and 0.74. Except for Zn in the control sample where it is considered as Considerably Contamination Factor as it falls within $3 \leq C_F^i < 6$, all the transfer factors calculated for cabbage are below the low and moderate Contamination Factor of $1 \leq C_F^i < 3$. The transfer factor and metal concentration in these vegetables were in agreement with the study by *Sharma et al.* [32].

It should be noted that the transfer factor is affected by a metal's bioavailability, amounts of metal in soil, the chemical form of the metal, plant absorption capabilities, and plant species growth rate [33]. The high transfer factor for Zn, Cd, and Pb in lettuce, as well as Cd and Pb in cabbage, may be ascribed to greater mobility of these heavy metals due to natural occurrence [37], besides anthropogenic activities in the soil and the lower retention of these metals in the soil [33]. Furthermore, increased pollution from wastewater drainage, solid waste management and sludge applications, solid waste burning, agrochemicals, and vehicular emissions may contribute to the higher concentrations of these heavy metals [38]. Although there was no obvious health danger to the local public from consuming individual heavy metals found in the vegetables, the risk could be multiplied when all of the heavy metals are considered together.

Monomial ecological risk (E_r^i) and potential ecological Risk Index (IR) of the potentially toxic metals in Lettuce, Cabbage, and the control sample

The monomial ecological risk is presented in Table 10 and 11 and the potential ecological risk in Table 12. It can be observed that among the metals examined, Cd in lettuce

Table 4: Average Conc. of the potentially toxic metals in water sample and the control (mg/L).

Mean concentration of the potentially toxic metals in water sample (mg/L)							
Location	Months	Zn	Mn	Cd	Pb	Cu	Ni
DB	Dec.	0.055	0.31	ND	0.04	0.13	0.09
	Jan.	0.01	0.12	0.003	0.05	ND	0.16
	Feb.	0.03	0.16	ND	1.14	ND	0.075
	Mar.	0.02	0.13	ND	0.21	ND	0.098
Control		0.002	0.15	ND	0.052	ND	0.04

Key: DB=Dambo Dam, while (ND) indicated that metal was not detected.

Table 5: Average conc. of the potentially toxic metals in the soil and the pontrol (mg/kg).

Mean concentration of the potentially toxic metals in soil sample (mg/L)							
Location	Months	Zn	Mn	Cd	Pb	Cu	Ni
DB	Dec.	5.55	103.46	0.16	14.26	ND	11.76
	Jan.	3.38	82.26	0.60	3.88	ND	13.52
	Feb.	5.33	86.68	ND	35.72	ND	7.73
	Mar.	14.23	175.92	0.412	33.85	3.86	11.94
Control		1.19	29.99	ND	2.40	2.40	3.32

Key: DB=Dambo Dam, while (ND) indicated that metal was not detected.

Table 6: Average Conc. of the potentially toxic metals in the Lettuce and the control (mg/ kg).

Mean concentration of the potentially toxic metals in Lettuce sample (mg/ kg)							
Location	Months	Zn	Mn	Cd	Pb	Cu	Ni
DB	Dec.	15.11	48.76	0.901	11.61	ND	9.10
	Jan.	15.46	142.18	0.81	11.63	ND	10.16
	Feb.	12.36	50.38	ND	30.35	ND	6.66
	Mar.	17.71	89.40	0.33	16.20	ND	4.85
Control		2.61	22.13	ND	ND	ND	1.84

Key: DB=Dambo Dam, while (ND) indicated that metal was not detected.

Table 7: Average Conc. of the potentially toxic metals in the Cabbage and the control (mg/ kg).

Mean Concentration of the potentially toxic metals in Cabbage sample (mg/kg)							
Location	Months	Zn	Mn	Cd	Pb	Cu	Ni
DB	Dec.	11.99	22.18	1.01	29.68	ND	12.72
	Jan.	10.34	16.94	0.75	18.32	ND	11.99
	Feb.	7.72	15.44	ND	37.33	ND	7.38
	Mar.	8.17	16.23	0.28	17.91	ND	7.47
Control		6.17	22.13	0.30	10.44	1.05	5.60

Key: DB=Dambo Dam, while (ND) indicated that metal was not detected.

Table 8: Transfer factor of the potentially toxic metals in Lettuce sample and the control (mg/kg).

Transfer factor of the potentially toxic metals in Lettuce sample (mg/kg)							
Location	Months	Zn	Mn	Cd	Pb	Cu	Ni
DB	Dec.	2.72	0.47	5.54	3.01	-	0.77
	Jan.	4.58	1.73	1.35	0.77	-	0.75
	Feb.	2.32	0.58	-	0.85	-	0.86
	Mar.	1.25	0.51	0.80	0.48	-	0.41
Control		2.19	0.74	-	-	-	0.56

Key: DB=Dambo Dam, while (-) indicated that metals are not detected in soil and Transfer factor not calculated.

Table 9: Transfer factor of the potentially toxic metals in Cabbage sample and the control (mg/kg).

Transfer factor of the potentially toxic metals in cabbage sample (mg/kg)							
Location	Months	Zn	Mn	Cd	Pb	Cu	Ni
DB	Dec.	2.16	0.21	6.19	2.08	-	1.08
	Jan.	3.06	0.20	1.25	4.73	-	0.89
	Feb.	1.45	0.18	-	1.05	-	0.96
	Mar.	0.57	0.09	0.69	0.53	-	0.63
Control		5.19	0.74	-	4.35	-	1.69

Key: DB=Dambo Dam, while (-) indicated that metals are not detected in soil and transfer factor not calculated.

has the greatest Monomial Ecological Risk of 230.72, followed by Pb; 25.720, Ni; 13.960, Zn; 10.861, and Mn; 3.289, which agrees with the work of *Limin* and *Changxu* [27]. A similar pattern was observed for the cabbage sample, with Cd having the highest Monomial Ecological Risk of 243.92, Ni; 106.47, Pb; 41.91, Zn; 7.24, and Mn; 0.51. Monomial potential ecological of Zn and Mn assessed for both vegetables between December to March are within $E_r^i < 40$ value considered as Low Risk. The Pb in cabbage was found to be between $40 \leq E_r^i < 80$ considered as been Moderate Risk. Finally, Cd in both vegetables and Ni in cabbage is in the range between $160 \leq E_r^i < 320$ considered as very high considerable Risk contamination factor.

The potential ecological Risk Index (RI) indicates the degree of heavy metal pollution and also evaluates the ecological risk caused by toxic metals in the environment. The highest RI was observed in cabbage; 400.24 and lettuce; 284.55, considered very high risk and considerable risk, respectively. In the control, the RI of 36.11 and 5.70 were observed respectively for cabbage and lettuce. The RI in both cabbage and lettuce are deemed very dangerous since according to the grade of Potential Ecological risk posed by toxic metals, their RI Values are in the range of $200 \leq RI < 400$ considered as considerably dangerous [23]. This implies that the inhabitants' intake of these vegetables may pose a high risk to their health.

CONCLUSIONS

In both water and soil, the concentrations of the potentially toxic metals analyzed are in the order Mn>Pb>Zn>Ni>Cd>Cu. However, for lettuce Pb was found to be higher than Mn. Furthermore, Zn, Mn, Cd, Pb, Cu, and Ni were all within the permissible limits. All the samples analyzed certain high levels of these metals, indicating evidence of contamination, which may be due to anthropogenic activity, such as the disposal of refuge and domestic waste containing these metals. The monomial ecological risk of these metals in both vegetables is in the order of Cd > Pb > Ni > Zn > Mn, in the vegetables studied, except for cabbage, where Ni exceeds Pb. Although there was no obvious health danger on the consumption of the vegetables, the risk could be multiplied when all of the heavy metals are considered together. The study also

Table 10: Monomial ecological risk (E_r^i) of the single potentially toxic metals in Lettuce sample and the control.

Sample I.D	Monomial Ecological Risk Index (E_r^i) of the single potentially toxic metals in Lettuce Sample					
	Zn	Mn	Cd	Pb	Cu	Ni
DB	10.86	3.29	230.72	25.72	0.00	13.96
Cont.	2.19	0.74	0.00	0.00	0.00	2.78

Key: DB= Dambo Dam

Table 11: Monomial ecological risk (E_r^i) of the single potentially toxic metals in Cabbage sample and the control.

Sample I.D	Monomial ecological risk (E_r^i) of the single potentially toxic metals in Cabbage sample					
	Zn	Mn	Cd	Pb	Cu	Ni
DB	7.24	0.69	243.92	41.91	-	106.47
Cont	5.19	0.74	0.00	21.74	-	8.45

Key: DB = Dam and Dambo Dam

Table 12: Potential Ecological Risk Index (IR) of the Potentially Toxic Metals in the Study areas and the Control.

Potential Ecological Risk Index (IR) of the potentially toxic metals in the three study areas				
Sample I.D	Lettuce	Grade of the Env. nt	Cabbage	Grade of the Env.nt
DB	284.55	Considerable Risk	400.24	Very High Risk
Cont.	5.70	Low Risk	36.11	Low Risk

Key: DB =Dambo Dam

revealed that the potential ecological risk index of both cabbage and lettuce are deemed very dangerous, as such intake of these vegetables may pose a high risk to their health. In line with it is necessary for continuous monitoring of heavy metals pollution around this area.

Received: Apr. 12, 2022 ; Accepted: Jun. 13, 2022

REFERENCES

[1] Khanna P., Assessment of Heavy Metal Contamination in Different Vegetables Grown in and Around Urban Areas. *Research Journal of Environmental Toxicology*, **5(3)**: 162(2011).

[2] Saatloo S. J. E., Saatlo M. E., Siosemarde M., Merufinia E.,Investigation and Measurement of Heavy Metals Amount (As, Pb, Cd, Hg) within Rivers Estuaries Located in the West Side of Urmia Lake, *Journal of Civil Engineering and Urbanism*, **4(3)**: 233-238 (2014).

[3] Sharma P., Dubey R. S., Lead Toxicity in Plants, *Brazilian Journal of Plant Physiology*, **17(1)**: 35-52 (2005).

[4] Prabu P.C.,Impact of Heavy Metal Contamination of Akaki River of Ethiopia on Soil and Metal Toxicity on Cultivated Vegetable Crops, *Electronic Journal of Environmental, Agricultural & Food Chemistry*,**8(9)**: (2009).

[5] Zand N., Chowdhry B.Z., Zotor F.B., Wray D.S., Amuna P., Pullen F.S.,Essential and Trace Elements Content of Commercial Infant Foods in the UK, *Food Chemistry*,**128(1)**: 123-128 (2011).

[6] Arora M., Kiran B., Rani S., Rani A., Kaur B., Mittal N.,Heavy Metal Accumulation in Vegetables Irrigated with Water from Different Sources, *Food Chemistry*,**111(4)**: 811-815(2008).

[7] Zhuang P., McBride M. B., Xia H., Li N., Li Z.,Health Risk from Heavy Metals *via* Consumption of Food Crops in the Vicinity of DabaoshanMine, South China, *Science of the Total Environment*,**407(5)**: 1551-1561 (2009).

[8] Sultana M.S., Rana S., Yamazaki S., Aono T., Yoshida S., Health Risk Assessment for Carcinogenic and Non-Carcinogenic Heavy Metal Exposures from Vegetables and Fruits of Bangladesh, *Cogent Environmental Science*, **3(1)**: 1291107 (2017).

[9] Guan Y., Shao C., Ju M., Heavy Metal Contamination Assessment and Partition for Industrial and Mining Gathering Areas, *International Journal of Environmental Research And Public Health*, **11(7)**: 7286-7303 (2014).

[10] Hussain A., Alamzeb S., Begum S., Accumulation of Heavy Metals In Edible Parts of Vegetables Irrigated with Wastewater and their Daily Intake to Adults and Children, District Mardan, Pakistan, *Food Chemistry*, **136(3-4):** 1515-1523 (2013).

[11] Suciu I., Cosma C., Todică M., Bolboacă S. D., Jäntschi L., Analysis of Soil Heavy Metal Pollution and Pattern in Central Transylvania, *International Journal of Molecular Sciences*, **9(4)**: 434-453 (2008).

[12] Kamunda C., Mathuthu M., Madhuku M., Health Risk Assessment of Heavy Metals in Soils from Witwatersrand Gold Mining Basin, South Africa, *International Journal of Environmental Research and Public Health*, **13(7)**: 663 (2016).

[13] Aiman U., Mahmood A., Waheed S., Malik R. N., Enrichment, Geo-Accumulation and Risk Surveillance of Toxic Metals for Different Environmental Compartments from Mehmood Booti Dumping Site, Lahore City, Pakistan, *Chemosphere*, **144**: 2229-2237 (2016).

[14] Kim J.Y., Lee J. H., Kunhikrishnan A., Kang D. W., Kim M.J., Yoo J. H., Kim W. I., Transfer Factor of Heavy Metals from Agricultural Soil to Agricultural Products, *Korean Journal of Environmental Agriculture*, **31(4)**: 300-307 (2012).

[15] Yahaya M., Heavy Metal Levels in Selected Green Leafy Vegetables Obtained from Katsina Central Market, Katsina, North-Western Nigeria, *African Journal of Pure and Applied Chemistry*, **7(5)**: 179-183 (2013).

[16] OlabimpeIyabo O., Oluwafemi J., Grace A. M., Oladele O., Heavy Metals and Some Physicochemical Parameters in the Soil of Major Domestic Dumpsites in Akure Township, ondo State, South-Western Nigeria, *International Journal of Engineering Technologies and Management Research*, **4(10)**: 26-32 (2017).

[17] Ahmed M., Matsumoto M., Ozaki A., Thinh N. V., Kurosawa K., Heavy Metal Contamination of Irrigation Water, Soil, and Vegetables and the Difference Between Dry and Wet Seasons Near a Multi-Industry Zone in Bangladesh, *Water*, **11(3)**: 583 (2019).

[18] Onianwa P. C., Fakayode S. O., Lead Contamination of Topsoil and Vegetation in the Vicinity of a Battery Factory in Nigeria, *Environmental Geochemistry and Health*, **22(3)**: 211-218 (2000).

[19] Campos-M M., Campos-C R., Applications of Quartering Method in Soils and Foods, *Int. J. Eng. Res. Appl.*, **7(1)**: 35-39 (2017).

[20] Egwu O.C., Casmir U.C., Victor U.C., Samuel U.C., Dickson M. A., Oluwanisola O. W., Evaluation and Ecological Risk Assessment of Selected Heavy Metal Pollution of Soils and Amaranthuscruentus and TelfairiaOccidentalis Grown Around Dump Site in Chanchaga Minna, Niger State, Nigeria, *Asian Journal of Environment & Ecology*, **1**: 16 (2019).

[21] Jamali M. K., Kazi T. G., Arain M. B., Afridi H. I., Jalbani N., Memon A. R., Heavy Metal Contents of Vegetables Grown in Soil, Irrigated with Mixtures of Wastewater and Sewage Sludge InPakistan, Using Ultrasonic-Assisted Pseudo-Digestion, *Journal of Agronomy and Crop Science*, **193(3)**: 218-228 (2007).

[22]Uddin A. H., Khalid R. S., Alaama M., Abdualkader A. M.,Kasmuri A., Abbas S. A., Comparative Study of Three Digestion Methods for Elemental, *Journal of analytical science and technology*, **7(1)**: 1-7 (2016).

[23] Wang B., Liu Y., Zhang Y., Shen F., Yang G., Zhang X.,Deng S., Degradation Process and Kinetics Study of Actual Urotropine Wastewater by Fenton Method, *Desalination and Water Treatment*, **160**: 219-228 (2019).

[24] Aktaruzzaman M., Fakhruddin A.N., Chowdhury M.A.,Fardous Z., Alam M.K., Accumulation of Heavy Metals in Soil and their Transfer to Leafy Vegetables in the Region of Dhaka Aricha Highway, Savar, Bangladesh, *Pakistan Journal of Biological Sciences: PJBS*, **16(7)**: 332-338 (2013).

[25] Mirecki N., Agic R., Sunic L., Milenkovic L., Ilic Z. S., Transfer Factor as an Indicator of Heavy Metals Content in Plants, *Fresenius Environmental Bulletin*, **24(11c)**, 4212-4219 (2015).

[26] Eugene R. W., Application of Environmental Chemistry: A Practical Guide for Environmental Professionals, Lewis Publication, London (2000).

[27] Limin M.,Changxu H., Water Quality Ecological Risk Assessment with Sedimentological Approach, Water Quality - Science, Assessments, and Policy, Kevin Summers, IntechOpen, (2019).

[28] Ogundele D. T., Adio A. A., Oludele O. E., Heavy Metal Concentrations in Plants and Soil along Heavy Traffic Roads in North Central Nigeria, *J. Environ. Anal.Toxicol.*, **5**: 334 (2015).

[29] Anonymous. Role of Zinc in Plant Culture/PRO-MIX Greenhouse Growing.www.pthorticulture.com>training-center (2021).

[30] Duressa T. F., Leta S., Determination of Levels of As, Cd, Cr, Hg and Pb in Soils and Some Vegetables Taken From River Mojo Water Irrigated Farmland at Koka Village, Oromia State, East Ethiopia, *International Journal of Sciences: Basic and Applied Research*, **21(2)**: 352-372 (2015).

[31] Santiago A. Stefanie H., Bastian M., and Edgar P., Manganese in Plants: From Acquisition to Subcellular Allocation Front. Plant Sci., (2020). https://doi.org/10.3389/fpls.2020.00300 Plant Nutrition Laboratory, Institute of Agricultural and Nutritional Sciences, Martin Luther University Halle-Wittenberg, Halle (Salle), Germany.

[32] Sharma A. Jatinder K. K. and Avinash K. N., Heavy Metals in Vegetables: Screening Health Risks Involved in Cultivation Along Wastewater Drain and Irrigating With Wastewater, *Springer Plus*., **5**:488 (2016).

[33] David S. Kacholi M.S., Levels and Health Risk Assessment of Heavy Metals in Soil, Water, and Vegetables of Dares Salaam, *Tanzania*, *Journal of Chemistry*, **2018**: (2018).

[34] WHO (1996) Permissible limits of heavy metals in soil and plants (Geneva: World Health Organization), Switzerland.

[35] Onder S., Dursun S., Gezgin S., Demirbas., Determination of Heavy Metals Pollution in Grass and Soil of City Center Green Area (Konya Turkey). *Pol J Environ Stud*, **1**: 145-154 (2007).

[36] Hjortenkrans D. Diffuse Metal Emission to Air from Road traffic. A Case Study of Kalmar, Sweden. Environ Sci Sect Bullet, pp: 1-55 (2003).

[37] Alam M. G. M., Snow E. T., and Tanaka A., Arsenic and Heavy Metal Contamination of Vegetables Grown in Samta Village, Bangladesh, *Science of the Total Environment*, **308(1-3)**: 83–96 (2003).

[38] Intawongse M., Dean J. R., Uptake of Heavy Metals by Vegetable Plants Grown on Contaminated Soil and their Bioavailability in the Human Gastrointestinal Tract, *Food Additives & Contaminants: Part A*, **23(1)**: 36-48 (2006).

[39]Chen l., Liao Y., Ma X., Niu Y., Effect of Co-combusted Sludge in Waste Incinerator on Heavy Metals Chemicals Speciation and Environmental Risk of Horizontal Flue Ash, *Waste Manag.* **102**: 645-654 (2020).

[40] McLaughlin M., Singh B.R., Cadmium in Soils and Plants,© Kluwer Academic Publishers, Agricultural University of Norway, Norway (1999).