Heavy Metal Pollution in Soil, Water and Vegetables in Dar es Salaam – Tanzania

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Abstract

Heavy metals (Cu, Cr, Cd and Pb) in soil and vegetable leaves (Amaranthus blitum, Ipomea batata and Cucurbita maxima) were determined along Msimbazi River, in Dar es Salaam – Tanzania. Atomic Absorption Spectrophotometer was used to analyse all samples, and results obtained were compared with standard limits. Laboratory results showed that concentrations of heavy metals in soils were all below maximum limits. Vegetable samples had copper concentrations below standard limits. The concentrations of Cadmium, Lead and Chromium were between 0.309 ± 0.01 mg/Kg and 0.331 ± 0.01 mg/Kg, 2.526 ± 0.01 mg/Kg and 9.143 ± 0.11 mg/Kg, and 1.118 ± 0.01 mg/Kg and 13.981± 0.87 mg/Kg, respectively, that exceeded maximum standard limits of 0.02, 2 and 1.3 mg/kg, respectively. The presence of such elevated levels of dangerous heavy metals in edible vegetables indicates a potential health risk to urban consumers of vegetables grown along Msimbazi River, through long-term dietary intake. The trends for heavy metal concentrations in soil, water, and vegetables, for the past 20 years, for the same study site, were also established. The trend for average concentrations of heavy metals in soils and vegetables showed average increases from year 2000 to 2010 and decreases from 2010 to 2020. On the contrary, concentrations of heavy metals in water showed an increase from year 2000 through 2020, except for chromium that decreased from 2010 to 2014. This information is vital for policy makers and other concerned stakeholders in monitoring urban vegetable farming activities in major cities especially Dar es Salaam.

Keywords: heavy metal, soil, vegetables, pollution, urban farming, Msimbazi River

Introduction

In these modern times, urban farming brings a precious opportunity for tangible improvements in food availability, health, and economic conditions, as well as environmental sustainability (Kihampa and Mwegoha, 2010; Mwegoha and Kihampa, 2010; Orsini *et al.,* 2013). Urban agriculture is a common endeavour across the globe and is done in a bunch of both traditional and modern farming systems. As of recent, most urban citizens have found urban farming to be a new way of income generation, and a proper way of obtaining the required nutritional supplements in their daily meals (Sarker *et al.,* 2022). Urban farming is normally undertaken by individuals or groups of people or associations/organizations such as households, nurseries, schools, hospitals, prisons, factories, as well as other private entities (Bahemuka and Mubofu, 1999).

However, with the current developmental pace in major cities, environmental pollution from heavy manufacturing and production industries such as fishing, agriculture, transportation, mining, and construction is rapidly becoming a chronic phenomenon for most developing countries (Rehman *et al.,* 2013). Currently, heavy metal contamination in farm soils, in major cities, is mostly a result of industrial activities that were undertaken years ago. Furthermore, the practice of using petroleum products such as fuels; agrochemicals and pesticides in farms; contribute to a large portion, in heavy metal and hydrocarbons pollution to the natural environment (Ezeonyejiaku and Obiakor, 2017). However, soil pollution depends on the bioavailability of heavy metals in that particular soil, as well as a number of other physico-chemical properties of soil, such as soil texture, clay content, organic matter, pH, sulphate, carbonate, and hydroxide (Kihampa and Mwegoha, 2010). Although metals such as Copper, Manganese, Cobalt, Zinc and Chromium are essential nutrients for plant growth, in soils (Kihampa and Mwegoha, 2010; Sarker *et al.,* 2022), high levels of these metals can lead to poisoning (Zwolak *et al.,* 2019). Metals such as Arsenic, Lead, Cadmium, Mercury, Chromium and Nickel, in particular, are scientifically termed as being dangerous to humans' health, and are well connected with acute and chronic poisoning in animals, growth abnormalities in children and blood neutrophils (Leonard *et al.,* 2012; Mahurpawar, 2015; Sarker *et al.,* 2022).

Although, production and consumption of fresh vegetables is advocated by nutritionist and health scientists, to be a good practice, for better human health, urban farming still remains one of the major concerns for heavy metals and other toxic chemicals (such as pesticides and agrochemicals) contamination and bioaccumulation in edible vegetables (Kihampa and Mwegoha, 2010; Sarker *et al.,* 2022). Animals, especially human beings may easily get poisoned by heavy metals as well as other toxic chemicals from edible vegetables through ingestion of contaminated vegetables (Zhou *et al.,* 2020).

Like in many other cities, urban agriculture is not a new phenomenon in Dar es Salaam city, Tanzania. There exists a common practice of cultivating vegetables along the banks of Msimbazi River that passes through the city. Msimbazi River, is known to support farming of various vegetables species such as African spinach (*Amaranthus blitum*), Sweet potatoes (Ipomea batata) and Pumpkin (*Cucurbita maxima*). However, research (Mashauri and Mayo, 1990; Mwegoha and Kihampa, 2010) have shown that Msimbazi River contains elevated concentrations of Lead, Copper, Zinc, Chromium, Iron, Cadmium and Mercury. Poor solid waste management, poor sewage drainage systems as well as unmanaged industrial effluents are named to be major pollution sources for the River (Mwegoha and Kihampa, 2010). Furthermore, research has shown that the levels of heavy metals in soil, water and vegetables grown along Msimbazi River increased significantly from year 2000 to 2010s (Othman, 2001; Othman, 2002; Kihampa and Mwegoha, 2010; Mwegoha and Kihampa, 2010; Aselina, 2014). Additionally, there are very few studies conducted between 2010 and 2020 to measure the levels of heavy metals in soil, water, and vegetables along Msimbazi River. One study by Kacholi and Sahu (2018) was conducted to determine levels of only two heavy metals (Cu and Pb) in water, and was not specifically for Msimbazi River, and so it cannot be taken as a conclusive study on Msimbazi River. This study, therefore, is aimed at determining current (year 2020s) levels of heavy metals in agricultural soils and selected edible vegetable leaves grown along Msimbazi River, in Dar es salaam city, Tanzania. The study also aims to present a 20 years (2000 to 2020) trend regarding heavy metal concentrations in soil, water and vegetables grown along Msimbazi River, Dar es Salaam.

Materials and Methods

Site description

This study was undertaken in Dar es Salaam City, Tanzania (Fig. 1), where a 45 km long Msimbazi River is found. This river originates from the highlands of Pugu Forest Reserve and receives untreated and semi treated effluents from several tributaries that pass through highly industrial areas of Dar es Salaam. These include, but not limited to; food processing, steel, textile, paints, batteries, electromechanical industries, as well as abattoirs. Msimbazi River receives water from Luhanga, Sinza and Zimbire tributaries, and from Mambizi, Ubungo, Kimanga, Kinyenyele and Kwangula sub tributaries. Main activities conducted along Msimbazi River, include vegetable farming, fishing, and sand mining for construction. In this study site, vegetable faming is practiced throughout the year, and the study was conducted between March and April 2020, which is a fairly wet season. The physicochemical parameters of Msimbazi River were assumed to be similar to that reported by

Mwegoha and Kihampa (2010).

Sample collection, preparation, and analysis

Sampling locations are as shown in Table 1 and Figure 1. Two locations were selected including Jangwani area, behind Kajima industrial area, where Luhanga stream joins Msimbazi River (MSB1), and Ulongoni, where Zimbiri stream joins Msimbazi River (MSB2). Vegetable samples from African spinach (*Amaranthus blitum*), Sweet potatoes (*Ipomea batata*) and Pumpkin (*Cucurbita maxima*) were collected from the two locations along the cultivated banks of the river Msimbazi. A total of 32 samples were collected: 8 for soil and 24 for vegetable leaves. All sample analysis were conducted at ADRHI University laboratories, in Dar es Salaam.

Figure 1: Msimbazi River, its main tributaries and sampling locations (MSB 1 and MSB 2), *Source:* Kironde, 2016

Soil samples

For heavy metals in farm soils, eight soil samples were collected, to a depth of 15 cm. Soil sample preparations were done using standard procedures as recommended by Adams (2017). As recommended by Mwegoha and Kihampa (2010), soil sample analysis was performed by using Atomic Absorption Spectrophotometer (AAS, Perkin Elmer AAnalyst 100), equipped with Perkin Elmer HGA 850 Graphite Furnace and Perkin Elmer AS 800 Autosampler.

Vegetable sample collection and preparation

For heavy metals in selected edible vegetables (*Amaranthus blitum, Ipomea batata* and *Cucurbita maxima*), twenty-four samples were collected from the farms, and sample preparation was performed as stipulated in standard procedures (Kihampa and Mwegoha, 2010).

Table 1: Sample description

Sample ID	Sample type/name	Sample location
MSB 1-1	Soil	Kigogo
MSB 2-1	Soil	Ulongoni
MSB 1-2	*Amaranthus blitum*	Kigogo
MSB 1-3	*Ipomea batatas*	Kigogo
MSB 1-4	*Cucurbita maxima*	Kigogo
MSB 2-2	*Amaranthus blitum*	Ulongoni
MSB 2-3	*Ipomea batatas*	Ulongoni
MSB 2-4	Cucurbita maxima	Ulongoni

Vegetable sample extraction and analysis

Vegetable samples extraction was done by using Nitric acid-perchloric acid digestion method, as suggested by Carranzo, (2013). By using standard procedures, heavy metals in vegetable samples were analyzed using Atomic Absorption Spectrophotometer (AAS, Perkin Elmer AAnalyst 100), equipped with Perkin Elmer HGA 850 Graphite Furnace and Perkin Elmer AS 800 Autosampler, having a detection limit of 0.01 ppm; slit width of 0.70 nm; and 228.8, 357.9, 324.8 and 283.3 nm as wavelength for Cd, Cr, Cu and Pb, respectively.

Statistical analysis

The calculations of average concentrations of heavy metals in farm soils and the selected vegetable leaves were done using a statistical package STATISTICA.

Trend analysis for heavy metals concentrations in soil, water, and vegetables along Msimbazi River

Levels of heavy metals in soil, water, and vegetables along Msimbazi River between year 2000 and year 2020 were compared at intervals of 10 years (2000, 2010 and 2020). Both secondary data (2000, 2010 and 2018) and primary data (2020) were utilized in this process (Othman, 2001; Othman, 2002; Kihampa and Mwegoha, 2010; Mwegoha and Kihampa, 2010; Aselina, 2014; Kacholi and Sahu 2018). The acquired data were used to produce graphs showing concentrations of Copper, Cadmium, Lead and Chromium in soil, water and vegetables along Msimbazi River, Dar es Salaam, for years; 2000, 2010 and 2020.

Results and discussion

Heavy metal concentrations in soil

Table 2 and Figure 2 display heavy metal concentrations for Copper, Cadmium, Lead and Chromium in soils for the two sites, MSB 1 and MSB 2. Results indicate that, for each heavy metal (except Cadmium), highest concentrations are found at sampling location MSB 1 (Kigogo) as compared to MSB 2 (Ulongoni). The reason is that MSB 1 is fairly on the downstream side of the river as compared to MSB 2 which is much closer to the main source of the river Msimbazi (Pugu Forest), that is usually less polluted (Fig. 1). Thus, soils found at MSB 1 are more likely to be polluted due to the influence of effluents received from several tributaries i.e., Zimbiri, Kinyerezi and Luhanga before reaching site MSB 1. Furthermore, Msimbazi River passes through highly populated areas, with many manufacturing industries (Gongo la mboto, Ukonga, Vingunguti and Tabata), before reaching site MSB 1. This is also the main reason why heavy metals concentrations at MSB 1 are higher than at MSB 2 (Fig. 2).

Lead concentrations were found to be maximum (18.13 ± 0.91) mg/kg at sampling location MSB 1 and minimum (7.17 ± 0.77) mg/kg at sampling point MSB 2. Elevated values of lead at MSB 1 may be associated with existence of the three highly polluted streams (Zimbiri, Kinyerezi and Luhanga) (Mwegoha and Kihampa, 2010; Leonard *et al.,* 2012), that pass through highly populated areas with many automobile garages and car wash stations, that release Pb metal (from car batteries), as well as hydrocarbons to the streams. Additionally, poor solid waste management practices by city dwellers, especially dumping household wastes close or into the river, has highly contributed to heavy metals pollution to Msimbazi River. Concentrations of Pb in soil at all sampling locations did not exceed the WHO (1996)

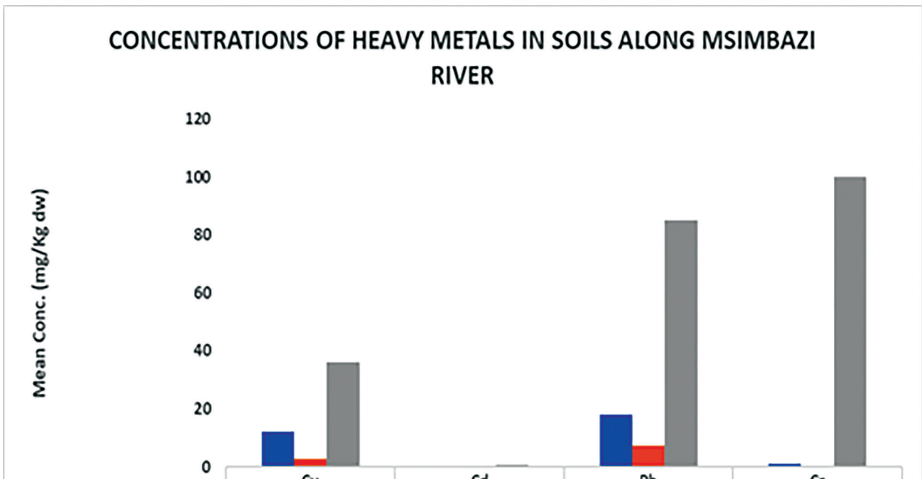
Table 2. Heavy metal concentrations in farm soils and vegetable leaves

S/N	SAMPLE	Mean concentration ± SD (mg/kg dw) at 95% CL (n = 4)			
		Cu	Cd	Pb	Cr
MSB 1-1	Soil	12.31 ± 0.81	BDL	18.13 ± 0.91	0.94 ± 0.14
MSB 2-1	Soil	2.94 ± 0.50	BDL	7.17 ± 0.77	0.17 ± 0.01
Permissible levels in Soils as per WHO (1996)		36	0.8	85	100
MSB 1-2	*Amaranthus blitum*	2.729 ± 0.01	BDL	9.143 ± 0.11	BDL
MSB 1-3	*Ipomea batatas*	2.660 ± 0.05	0.309 ± 0.01	BDL	BDL
MSB 1-4	*Cucurbita maxima*	3.265 ± 0.11	BDL	2.526 ± 0.01	BDL
MSB 2-2	*Amaranthus blitum*	2.149 ± 0.02	0.331 ± 0.01	BDL	13.981± 0.87
MSB 2-3	*Ipomea batatas*	2.807 ± 0.04	BDL	6.661 ± 0.31	1.118 ± 0.01
MSB 2-4	*Cucurbita maxima*	2.343 ± 0.14	BDL	7.028± 0.12	BDL
Permissible levels in Plants as per WHO (1996)		10	0.02	2	1.3

MSB 1: Kigogo, MSB 2: Ulongoni, BDL: Below Detection Limit, SD: Standard Deviation, CL: Confidence Level, n: sampling frequency, dw: dry weight, WHO: World Health Organization

maximum limit of 85 mg/kg for soils. Similar findings were published by Mwegoha and Kihampa (2010) and Leonard *et al.* (2012). Cadmium concentrations were found to be below detection limit at all sampling locations.

Maximum concentration of Chromium was found to be 0.94 ± 0.14 mg/kg at sampling point MSB 1 and the lowest concentration was 0.17 ± 0.01 mg/kg at MSB 2, with most of samples being below the WHO (1996) maximum limit of 100 mg/kg for soils. High levels of Chromium at MSB 1 may be attributed by the nature of the four areas in which the river passes (Gongo la mboto, Ukonga, Vingunguti and Tabata) before reaching the sampling point. These areas are highly populated areas, with a lot of active manufacturing industries that discharge polluted effluents to Msimbazi iver. (Mwegoha and Kihampa, 2010) Solid waste dumping may also be another accompanying problem. Same findings were reported by Mwegoha and Kihampa (2010). Copper concentration was maximum (12.31 ± 0.81) mg/kg at sampling location MSB 1 and minimum (2.94 ± 0.50) mg/kg at sampling point MSB 2. Ulongoni area, where MSB 1 is located features plumbing works and manufacture of electroplating materials, that may have attributed to the rising of the concentration of Cu at this location. However, concentrations of Cu in all soil samples were found to be below the WHO (1996) recommended limit of 36 mg/kg for soils. The results are in contrast with what was published by Mwegoha and Kihampa (2010), 10 years ago. However, the current study was undertaken in the wet season, in which, probably most of the Cu in the soil had been washed by rain, or else, the 10-year time interval has forced some of the polluting activities i.e. industrial activities to close down or to change into other environmental friendly ways of disposing of waste materials from their industries. Furthermore, it is evident that, as of recent, a lot of environmental awareness campaigns (SOWB, 2015; LCMO, 2016; IUCN, 2018) have been undertaken, national wide, to support efforts towards environmental protection, especially on natural resources such as water bodies (river, springs, wells and lakes). This has particularly improved communities ‘environmental knowledge on waste handling and environmental protection at large. Additionally, many manufacturing industries that used to apply old technologies have now changed into new environmentally friendly technologies that do not pollute the environment as much as it used to be. For instance, nowadays, most manufacturing industries do not apply firewood and charcoal as energy sources, instead, they use electricity



	Cu	Cd	Pb	Cr
MSB1	12.31	0	18.13	0.94
MSB2	2.94	0	7.17	0.17
STANDARD LIMITATION	36	0.8	85	100

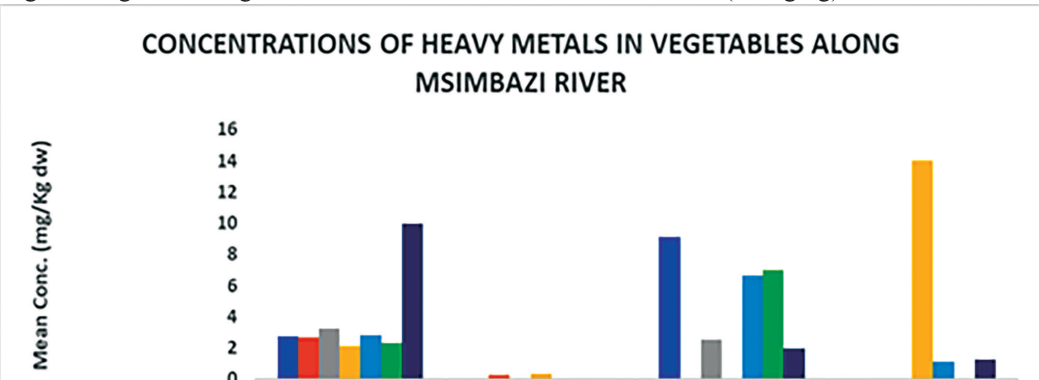
Figure 2: Heavy metals concentrations in farm soils

or gas or at least petroleum products, which are less polluting that wood products.

Heavy metals concentrations in vegetables

Mostly, urban agriculture is done through irrigation (Kihampa and Mwegoha, 2010; Leonard *et al.,* 2012). However, irrigation using polluted water is believed to cause soil pollution, especially heavy metals pollution through the process of nutrients uptake by plants (Rehman *et al.* 2013). The mean concentrations of Cu, Cd, Pb, and Cr in leaves of *A. blitum, I. batatas* and *C. maxima* for this particular study are as indicated in Table 2 and Figure 3. Cu concentrations across the three vegetables were found to be below WHO maximum limit (10 mg/kg), with minimum and maximum concentrations of 2.149 ± 0.02 and 3.265 ± 0.11, respectively. This signifies that Cu is not one of the health threats for citizens consuming vegetables grown along Msimbazi River.

studies on the same site may bring different results due to rapid changes in urban planning, technological development, human civilization as well as government policies and priorities. Cr concentrations for *A. blitum* grown at MSB 2 was found to be (13.981± 0.87), which exceeds the WHO maximum limit (1.3 mg/kg) by far. This value possesses a healthy threat to citizens consuming A. blitum from MSB 2. Other vegetables had concentrations below the WHO maximum limit (Table 2). Cd concentrations for I. batatas grown at MSB 1 and A. blitum grown at MSB 2 were 0.309 ± 0.01 and 0.331 ± 0.01, respectively, and were found to be above WHO maximum limit of 0.02 mg/kg. The remainder of vegetables had concentrations below the WHO maximum limit (Table 2). Pb was found to be the most threatful heavy metal of all. Its concentrations were found to exceed the WHO maximum limit (2 mg/kg) across the three



	Cu	Cd	Pb	Cr
MSB1-2	2.73	0	9.14	0
MSB1-3	2.66	0.31	0	0
MSB1-4	3.27	0	2.53	0
MSB2-2	2.15	0.33	0	13.99
MSB2-3	2.81	0	6.66	1.12
MSB2-4	2.34	0	7.03	0
STANDARD LIMITATION	10	0.02	2	1.3

Figure 3: Heavy metals concentrations in vegetables

This is contrary to results by Kihampa and Mwegoha (2010) who reported Cu to exceed WHO maximum limit in foodstuff (4 mg/kg). One reason for this might be the difference in seasonality between the two studies, in that one was conducted in dry season while the other one was conducted in wet season. Another reason is that, 10-year interval between two

vegetables (Table 2). Pb concentrations for A. blitum grown in MSB 1 was 9.143 ± 0.11, for *C. maxima* grown in MSB 1 and MSB 2 were 2.526 ± 0.01 and 7.028± 0.12, respectively, and for I. batatas grown in MSB 2 was 6.661 ± 0.31. This possesses a great health threat for citizens consuming the three varieties of vegetables in both locations. Similar findings were reported by Kihampa and Mwegoha in 2010. Several factors may have contributed to the differences in heavy metals concentrations across vegetables, including the difference in physico-chemical nature of the soils from the two sampling locations, and the absorption mechanism of each vegetable for each metal (Voutsa *et al.,* 1996; Kihampa and Mwegoha, 2010).

Trend analysis for heavy metals concentrations in soil water and vegetables along Msimbazi River

Figures 4 to 6 describe trends for Cu, Cd, Pb and Cr in soil, vegetables and water, respectively, between year 2000 and 2020. As it is shown in Figures 4a, 5a and 6a; concentrations for all the heavy metals (Cu, Cr, Cd and Pb) seem to increase rapidly from year 2000 to 2010 (Othman, 2001; Othman, 2002; Kihampa and Mwegoha, 2010; Mwegoha and Kihampa, 2010). This could be attributed by several reasons, one being the rise of vegetable farming as a commercial business to urban dwellers especially in major cities like Dar es Salaam. It is said that between 2000 and 2010 there were a lot of campaigns regarding consumption of healthy meals in the form of balanced diets, so many urban citizens increased their demand on vegetables as an alternative to healthy meals. In this way, more vegetable farms were prepared, and hence more farm soils were polluted.

However, in 2020 concentrations for all heavy metals were found to decrease as compared to 2010 (Figures 4b, 5b and 6b). The reason may be timing of the study, in that the study was conducted in a fairly wet season, in that some heavy metals might have been washed away by rainwater. Additionally, it is believed that recent developments in urban farming

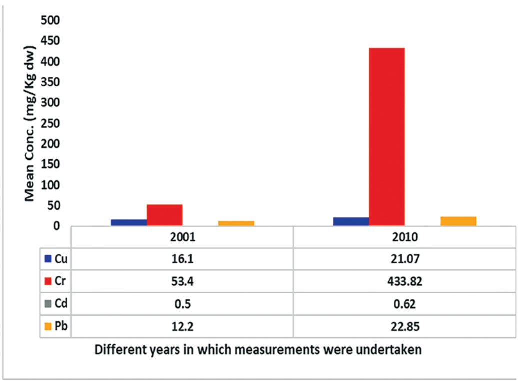


Figure 4a: Heavy metals in soil between 2000 and 2010

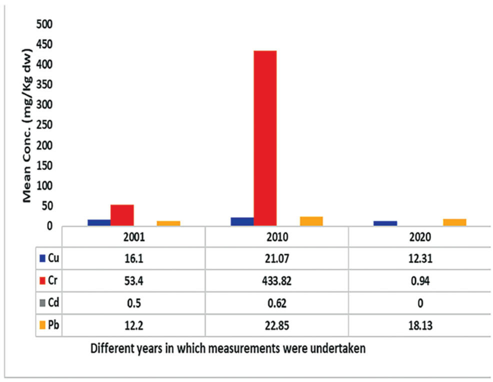


Figure 4b: Heavy metals in soil between 2010 and 2020

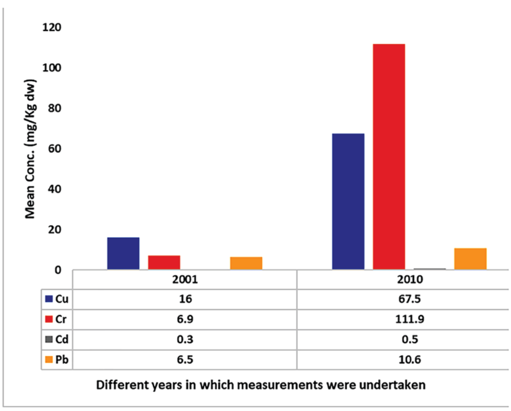


Figure 5a: Heavy metals in vegetables between 2000 and 2010

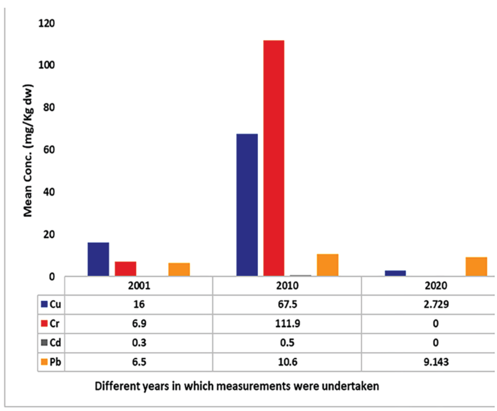


Figure 5b: Heavy metals in vegetables between 2010 and 2020

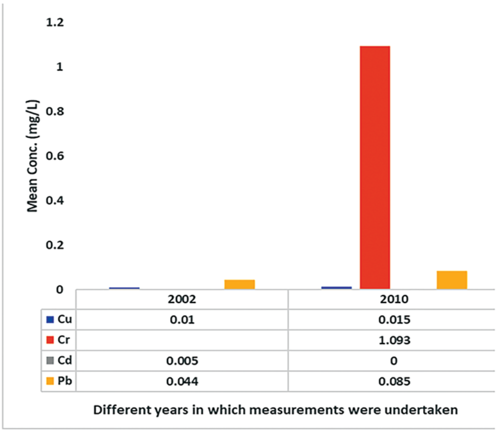


Figure 6a: Heavy metals in water between 2000 and 2010

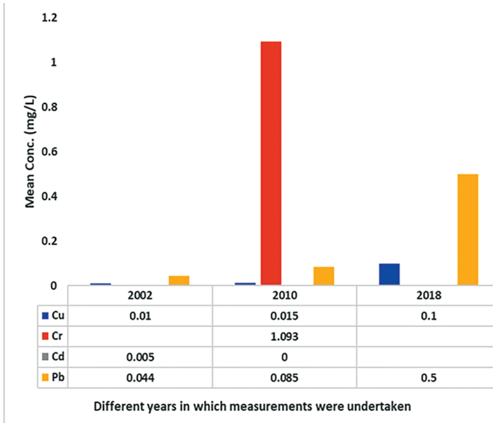


Figure 6b: Heavy metals in water between 2010 and 2020

have allowed many households to produce their own vegetables from their own backyards (home gardens), which in turn reduces the demand for vegetables from street vendors, which in turn discourages farming around surface water sources such as Msimbazi River in Dar es Salaam. Furthermore, the 10-year time interval has forced some of the polluting activities i.e. industrial activities to close down or to change into other environmental friendly ways of disposing of waste materials from their industries.

Conclusions

Findings from this study has shown that the trend for concentrations of heavy metals in soil, water and vegetables along Msimbazi River had increased rapidly from year 2000 to 2010. Further investigations have shown that the concentrations for heavy metals have decreased in all the three compartments in 2020 as compared to 2010. However, in 2020, vegetable samples were found to contain concentrations of Cd, Pb and Cr exceeding maximum limits by WHO (1996) standards. This phenomenon still indicates a potential health risk to urban consumers of vegetables grown along Msimbazi River, through long-term dietary intake. The author strongly recommends to relevant national regulatory authorities for regular monitoring of vegetable farming activities along Msimbazi River, to reduce excessive storage of dangerous heavy metals into the food chain.

Acknowledgments

The author wishes to acknowledge the work done by Ms. Verian Haule while she was a student at the University of Dodoma.

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