academicJournals

Vol. 8(27), pp. 1296-1303, 18 July, 2013
DOI 10.5897/SRE2013.5404
ISSN 1992-2248 © 2013 Academic Journals
http://www.academicjournals.org/SRE

Scientific Research and Essays

Full Length Research Paper

Heavy metals concentrations in selected areas used for urban agriculture in Dar es Salaam, Tanzania

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Accepted 12 July, 2013

This study was carried out to assess the concentration of heavy metals in selected areas used for urban agriculture in Dar es Salaam and compare them with permissible limit from the Tanzania Bureau of Standards (TBS) in order to establish risk levels. Samples were collected from six sites of Tazara mchichani, Ubungo darajani, Kigogo darajani, Temeke wailers, Tegeta and Bunju, which reflect frequently flooded and non-flooded areas and areas within the city and at the outskirts. The samples were analyzed for Zinc (Zn), Chromium (Cr), Cadmium (Cd), Lead (Pb) and Copper (Cu) as these are the common heavy metals in the city. The highest value of Cu (8.98 mg/kg), Zn (57.10 mg/kg) and Pb (33.70 mg/kg) were observed in Tazara Mchichani, which may reflect pollution from various manufacturing industries surrounding the areas including steel, iron, food processing and detergents. Bunju had the lowest Cu and Zn levels in the soil, averaging 1.92 mg/kg and 13.53 mg/kg, respectively, while Kigogo Darajani had the lowest Pb concentrations of 6.88 mg/kg. High and low values of Cr were observed in Tegeta and Temeke Wailes with the mean concentrations of 15.29 and 3.66 mg/kg respectively. The Cd level was high in Temeke Wailes, Kigogo Darajani and Tegeta with mean concentration of 0.26 mg/kg. The lowest Cadmium concentration (0.15 mg/kg) was observed at Tazara Mchichani. Heavy metal concentrations in the six sites were within the Tanzania Bureau of Standards (TBS) permissible limit, suggesting that no serious health hazards are expected. Flood seem not to influence toxic elements distribution as flooded area like Ubungo darajani, Tazara mchichani and Kigogo darajani had similar levels of concentrations of studied metals compared to non flooded areas of Temeke wailers, Tegeta darajani and Bunju.

Key words: Floods, risk levels, health hazards, permissible limit.

INTRODUCTION

Any effort that could increase the ability of urban population to feed themselves should be commendable. In that regard, urban agriculture has increasingly become important in feeding the growing urban population. It has become like a building block for creating sustainable urban settlement (Sawio, 1994). In Sub-Saharan Africa, urban agriculture is a common phenomenon and it is estimated that more than 40% of urban dwellers are involved in this activity (Foeken et al., 2002). In recent studies on urbanization in Africa, various researchers have documented with emphasize the practices of urban and peri urban agriculture. This is because such practices have become like a surviving strategy for urban dwellers. In Dar es Salaam, urban agriculture involves keeping livestock, cultivation of fruit trees and the most important aspect, vegetable production.

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Urban agriculture in Dar es Salaam takes place in home gardens (in backyards) and in open spaces such as river valleys, institutional areas and areas owned by the municipalities (Dongus, 2000). Irrespective of the importance of urban agriculture, there are various challenges facing urban farmers in the city. One of these challenges is water availability. Due to poor water supply, urban farmers use water from wells and rivers for irrigation and in some cases rainfall during wet season (Jacobi et al., un-dated; Dongus, 2000). In most cases the safety of water used in urban areas is questionable because the sources are always not reliable. There is a possibility that water from these sources might be contaminated by various pollutants, including heavy metals. Dongus (2000) and Quarshie et al. (2011), further revealed that in many cases vegetable farmers in Dar es Salaam have complained about contaminated water used for irrigation. This implies that it is likely that irrigated water in the city is contaminated by pollutants from various sources such as manufacturing industries, domestic and agrarian-based pollutants. The situation may be complicated during floods because large amount of heavy metals from different sources are likely to be washed into valleys including those that are used for crops and vegetable production. This is due to the fact that floods, sewerage systems, river flows, air and water vapour all act as the medium for heavy metals distribution. In Msimbazi valley for example, crops are irrigated by polluted water with heavy metals or exposed to polluted air which can eventually bring hazards to consumers' health (Sawio, 1994). When water contaminated by heavy metal is used for irrigation chances are that the concentration of such metals in the soils might be high and eventually absorbed by plants and passed in to human being. If these metals are consumed by human beings they might cause serious health effect.

Heavy metals might lead to very serious health effects to consumers of vegetables and other foods grown in urban areas if their concentration levels exceed the permissible limits as stipulated by the Tanzania Bureau of Standards (TBS) or the World Health Organization (WHO) (Mmolawa et al., 2011; Quarshie et al., 2011). Some of the general impacts of higher concentrations of heavy metals in soils include retarded plant growth causing problems in nutrient uptake, physiological and metabolic processes. Many heavy metals are considered as serious pollutants because of their toxicity nature, persistent and non-degradable conditions in the environment (Nwachukwu et al., 2010). Accumulation of heavy metals in the body can happen only when one consumes vegetables or other food types grown in the contaminated area because plants have ability to accumulate heavy metals and pass them along the food chain (Singh et al., 2010; Yang and Wei, 2010). It is indicated further that bio toxic effects of heavy metals depend upon the concentrations and oxidation states of heavy metals, kind of sources and mode of deposition. Regardless of the danger heavy metal poses to urban consumers, little is known on their concentration in the soils in different areas used for urban agriculture hence suitability of these areas for agricultural activities in the Dar-es-Salaam City. This study was therefore set to examine the concentrations of heavy metals in the soils of the selected areas used for urban agriculture in Dar es Salaam

Study area

The study was carried out in Dar es Salaam, Tanzania. The City of Dar es Salaam is located between latitudes 6.36° and 7.0° to the south of Equator and longitudes 39.0° and 33.33° to the east of Greenwich. The city is divided in to three Municipalities namely Temeke, Kinondoni and Ilala. It borders the Indian Ocean on the East and the Coast region to the West, South and North. The City experiences a modified equatorial climate. It is generally hot and humid throughout the year with an average temperature of 29°C. The average rainfall is 1000 mm (lowest 800 mm and highest 1300 mm) (URT, 2004). Soils in Dar es Salaam are geological sub-soils dominated by marine limestone (Dongus, 2000). Dongus (2000), further stated that; "soils found in coastal region are mainly sandy clays and clayey sands in the coastal plain, some rendzinas on Msasani Peninsular, whereas the soils near the edge of the plain to the inland Plateau are coarse sands (Colluvium). In the main river valley systems that go across the coastal plain (e.g. Msimbazi, Mzinga), mixed alluvial deposits (sands, silts and clays) are found. Thus the soils in Dar es Salaam Region are not particularly fertile". Six study sites selected were from Kinondoni Municipality (four sites), Ilala Municipality (one site) and Temeke Municipality (one site). Apart from flooded and non flooded factors, sites were selected based on the accessibility, use of irrigated water from a river or stream and willingness of owners to allow soil samples collection from their sites. In most cases, urban farmers were not willing to allow soil sample collected from their gardens fearing to be told to vacate in case soils in their site would be found with high concentration of heavy metals. Figure 1 shows the map of Dar es Salaam with six study sites.

MATERIALS AND METHODS

Soil sampling

Soil samples were collected from selected six different sites used for urban agriculture in Dar es Salaam. Some of these areas normally flood and some do not (Table 1). In these areas, vegetables such as spinach, chinese, cabbage, legume leaves, salads, okra, tomato and onions, fruits such as mangoes, bananas, lemons, oranges as well as maize and beans are cultivated (Figure 2).

In each type of the site identified, 3 replicates of soil composite

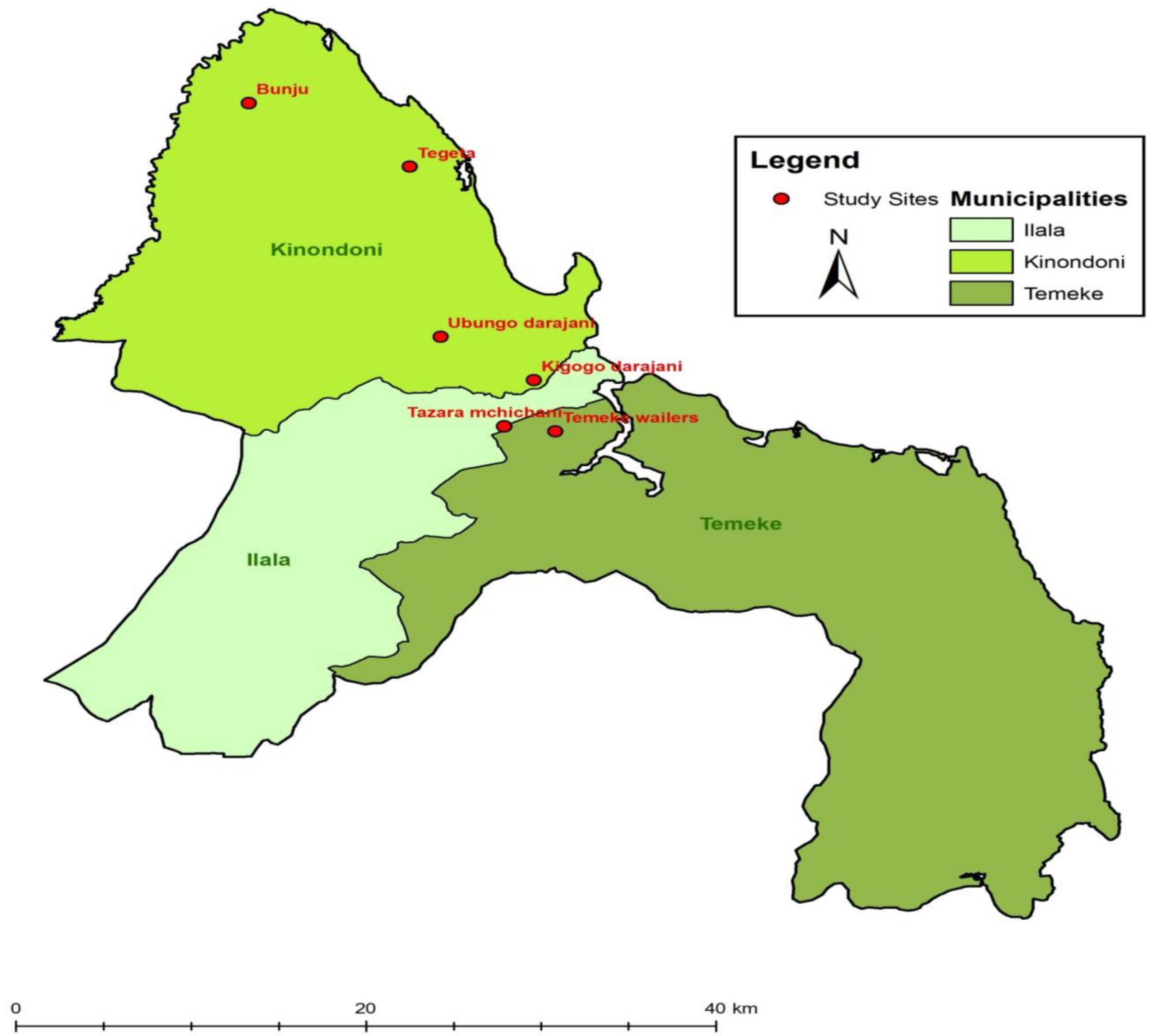

Figure 1. Map of Dar es Salaam showing six study sites in three Municipalities of Kinondoni, Ilala and Temeke (Source: Map created by Alison Thorpe of the University of Fraser Valley, BC, Canada).

samples were collected with a hand auger and plastic shovel using the procedures detailed in Quarshie et al. (2011). Samples were collected from three different depths: 0-20 cm, 20-40 cm, and 40-60 cm, and packed in polyethylene bags. A total of 54 soil samples were therefore collected from all the six sites (3 replicates x 3 sampling depths x 6 sites). The samples were then air-dried and sieved through a 2-mm sieve and analyzed for Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb) and Zinc (Zn). The analysis was limited to the most common heavy metal elements in Dar es Salaam due to their health hazards.

Soil analysis

Soil samples collected were taken to the Environmental Sciences Laboratory at Ardhi University for processing and chemical analysis. The samples were first dried in an oven at 40°C for 48 h and ground to pass through a 2 mm sieve and then digested in a 3:1 solution of HCL and HNO_3. Digested solutions were then analyzed for Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb) and Zinc (Zn) using Atomic Absorption Spectrometer (AANALYST 100/300 Perkin Elmer instrument F), following procedure described by HACH, SIW-1 Soil and irrigation water manuscript. This procedure involves weighing 0.5g of the dry soil into a graduated test tube and adding 2 mls of aqua regia solution (3 parts of HCL to 1 part HNO_3). The mixture was then digested on a hotplate at a temperature of 95°C and allowed to cool at room temperature. The digests were diluted to 10 ml with de-ionized water and left to settle overnight. The next day, the supernatant was analysed for heavy metals using Atomic Absorption Spectrometer.

Statistical analysis

Graphical analysis of residuals was employed to test for normality and constant variance of the soil toxic elements concentrations

Table 1. Characteristics of various sites where the samples were collected.

S/N	Areas used for urban agriculture	Characteristics of an area
1.	Ubungo Darajani-Kinondoni district (River valley)	-Located by the river bank / valley, -Frequently flooded area especially during heavy rain seasons (no vegetable productions during rainy season due to floods) -Surrounded by large trees
2.	Kigogo Darajani – Ilala district (River valley)	-Located on the river bank / valley, -Frequently flooded area especially during heavy rain seasons (no vegetable productions during rainy season due to floods) -Surrounded by large trees
3.	Tazara Mchichani gardens (Temeke district)	-Located in a shallow (seasonal) river bank / valley -Floods very rare (not always except in seasons when rainfall is extremely high) -Surrounded by few small trees
4.	Tegeta vegetable gardens (Kinondoni district)	-Located in a shallow (seasonal) river bank / valley -Floods very rare (not always except in seasons when rainfall is extremely high) -Surrounded by few small trees
5.	Temeke Wailers vegetable gardens (Temeke district)	-Located very close (within 50m) to a busy highway -Does not experience any flood -Not surrounded by any trees, almost bare area
6.	Bunju farm (Kinondoni district)	-Does not experience and flood -Urban agroforestry (trees, vegetables and other crops as well as domestic animals kept together) -Surrounded by large trees.

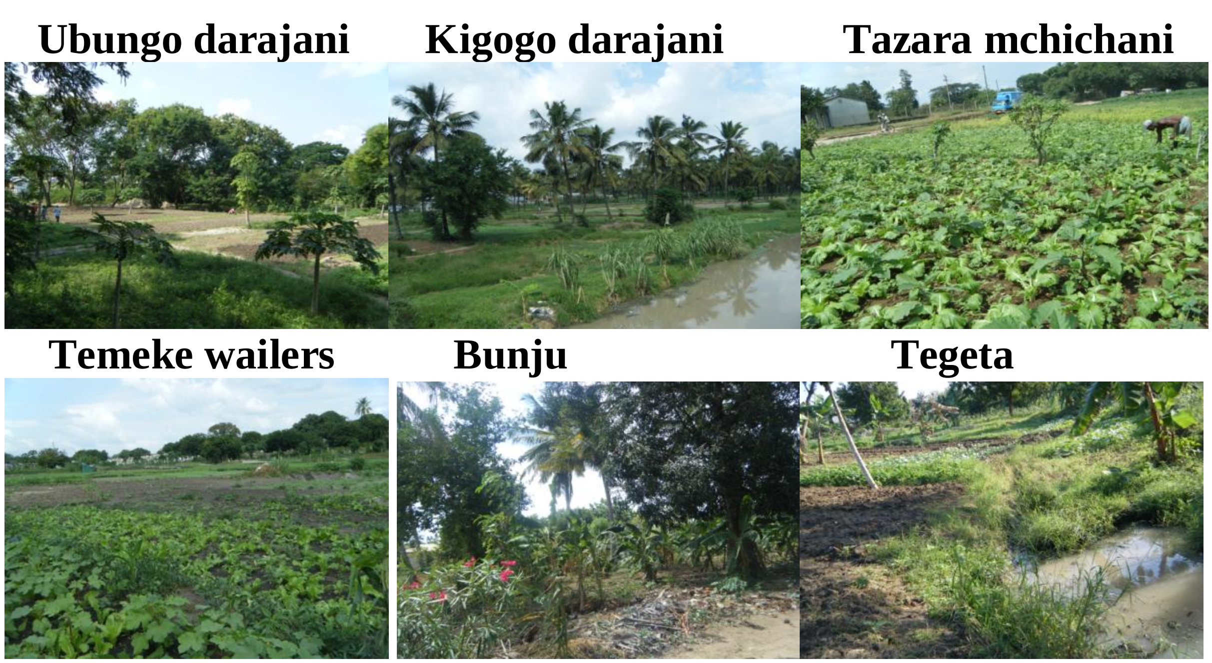

Figure 2. Plate showing six photos of the study sites where samples were collected

Table 2. Concentrations of heavy metals in vegetable producing areas in Dar-es-salaam, Tanzania.

Site	Parameter (mg/kg)				
	Cu	Zn	Pb	Cr	Cd
TAZARA MCHICHANI	$8.98^{a} \pm 1.865$*	$57.10^{a} \pm 16.291$	$33.70^{a} \pm 15.933$	$4.67^{a} \pm 2.419$	$0.15^{a} \pm 0.025$
TEMEKE WAILERS	$6.85^{ba} \pm 2.107$	$46.82^{ba} \pm 13.995$	$11.87^{a} \pm 4.024$	$3.66^{a} \pm 2.473$	$0.26^{a} \pm 0.045$
UBUNGO DARAJANI	6.13ba±1.697	$32.05^{bac} \pm 6.335$	$13.67^{a} \pm 6.085$	$5.04^{a} \pm 2.199$	$0.23^{a} \pm 0.041$
KIGOGO DARAJANI	5.45ba±0.444	$28.00^{bac} \pm 3.585$	$6.88^{a} \pm 0.686$	$11.50^{a} \pm 3.514$	$0.26^{a} \pm 0.035$
TEGETA	4.36ba±0.935	$21.58^{bc} \pm 6.177$	$9.04^{a} \pm 1.849$	$15.29^{a} \pm 4.156$	$0.26^{a} \pm 0.044$
BUNJU	1.92b±0.538	$13.53^{c} \pm 4.741$	$10.78^{a} \pm 6.089$	$5.93^{a} \pm 3.519$	$0.18^{a} \pm 0.029$
Pr > F	0.013	0.0017	0.0895	0.1295	0.2120
#MSD	5.3913	29.609	29.001	14.746	0.1473

(Mean ± standard errors, #MSD = Mean Significance Differences).

prior to the analysis of variance (ANOVA). Thereafter, a general linear model procedure in statistical analysis system (SAS) version 9.2 was used to run the analyses. The ANOVA adopted the randomized complete block design model to test the effects of the six sites, soil depth and their interactions on the concentrations of Cu, Zn, Pb, Cr and Cd. Following the ANOVA, significant treatment means were compared using Tukey's studentized range test. All statistical analyses described here were conducted at 5% level of significance and declared significant at $p < 0.05$.

RESULTS AND DISCUSSION

Concentrations of heavy metals in the selected area for urban agriculture in the city of Dar-es-Salaam

Table 2 presents the concentration of heavy metals in the soil for selected sites in the Dar-es-Salaam city. High amount of Cu was observed at Tazara Mchichani with the mean concentrations of 8.98 mg/kg while the lower amount was observed at Bunju with the mean concentrations of 1.92 mg/kg. In the five sites of Tazara Mchichani, Temeke Wailes, Ubungo Darajani, Kigogo darajani and Tegeta the concentration of Cu did not show any statistical difference except for Bunju which had very low levels. In general, Cu concentration is known to increase with the increase in Cu applications, soil pH, soil salinity, and exchangeable sodium and calcium (Wightwick and Mollah, 2006). This might be the reason for higher concentration of Cu in Tazara mchichani where manufacturing industries might be the source of Cu contamination. This area is surrounded by various manufacturing industries which produce steel, asbestos, detergents, cooking oil and mineral water. Sawio (1994) and Chen (2000), also reported that in most cases many agricultural fields located near industrial areas were polluted by industrial waste water. Chen (2000), identified sources of industrial pollution as heavy metals in hazardous waste, including materials from chemical production, dyeing, electroplating and heat treatment, scrap yards, service stations and tanning. There are also hazardous organic waste materials, including those from medical centers, as well as corrosive metal waste materials, including those from acid or alkali industrial plants and chemical engineering works. Tazara Mchichani is also close to a railway station where different goods are transported including copper from Zambia. Heavy metals from these pollutant sources might have found their way to shallow wells which are used for irrigation during periods of no rainfall. Similarly, Quarshie et al. (2011), noted terrestrial water bodies receives most of its solutes from soil where weathering is most active, and that through soil-water and soil atmosphere interactions, poisonous substances released into the atmosphere eventually return to the soil. As a result some plants are able to absorb heavy metals that settle on them through their leaves thereby entering the food chain. However, further research is needed to understand sources and dynamics of Cu in Tazara Mchichani soils given the high levels noted in this study and proximity to manufacturing industries and Cu transportation route, which are possible sources of pollutions. The lower Cu levels in soils under the agroforestry plot in Bunju probably reflect low pollution levels as this area is at the outskirt of the Dar-es-salaam city and away from the industrial sites or any other major urban sources of Cu pollution.

The amount of Zinc was observed to be high at Tazara Mchichani and Temeke Wailes with the mean concentrations of 57.10 and 46.82 mg/kg respectively while the lower amounts were recorded at Tegeta and Bunju with the mean concentrations of 13.53 and 21.58 mg/kg respectively. The higher value of Lead was observed at Tazara Mchichani with the mean concentration of 33.70 mg/kg while the lower value was observed at Kigogo Darajani with mean concentration of 6.88 mg/kg. The range of lead observed (6.88 – 33.70 kg/kg) is close to previous results by Mwegoha and Kihampa (2010), at Jangwani (22.9 mg/kg) and Tabata shule (9.6 mg/kg) in Dar-es-salaam. Higher lead concentrations in Dar-es-salaam has been attributed to polluted stream (e.g. Luhanga stream) and effluents from car washing sites (e.g, Kigogo garage) which use reviser water for washing cars (Mwegoha and Kihampa, 2010).

Table 3. Concentrations of heavy metals by depths.

Depth (cm)	Parameters (mg/kg)				
	Cu	Zn	Pb	Cr	Cd
0-20	6.66[a] ± 1.154**	45.70[a] ± 8.785	18.23[a] ± 4.627	8.06[a] ± 2.520	0.24[a] ± 0.0317
20-40	5.67[a] ± 1.176	30.47[ba] ± 6.506	12.69[a] ± 2.940	7.61[a] ± 2.356	0.23[a] ± 0.029
40-60	4.52[a] ± 0.919	23.37[b] ± 6.237	12.05[a] ± 8.033	7.37[a] ± 2.256	0.19[a] ± 0.019
Pr > F	0.2335	0.0099	0.5900	0.9775	0.3254
[#]MSD	3.0684	16.85	16.51	8.39	0.08

(**Mean ± standard errors, [#]MSD = Mean Significance Differences).

Discharging effluents and solid wastes from these sites which contain oils and heavy metals are often directed to the rivers and streams and could be the possible source of higher values of Lead and other metal pollution in the city.

Values for Cadmium and Chromium did not show any statistical difference (Table 2). The higher mean concentrations of Cadmium and Chromium were 0.26 and 15.29 mg/kg respectively which were all observed at Temeke Wailers, Kigogo Darajani and Tegeta for Cadmium and Tegeta for Chromium. The lower mean values for Cadmium and Chromium were 0.15 and 3.66 mg/kg which were observed at Tazara mchichani and Temeke Wailers respectively. Comparatively higher value of Cr observed in Tegeta is possibly due to the presence of the cement factory which is located on the upstream of the sampled site. Mmolawa et al. (2011), observed that industrial activities emit heavy metals such as Cd, Cr, Fe and Cu. However, the Cr levels in Tegeta is much lower than 502.3 and 174.7 mg/kg found in Jangwani and Vingunguti areas, respectively in Dar-es-Salaam (Mwegoha and Kihampa, 2010). Jangwani is one of the frequently and heavily flooded city center areas, which may partly account for elevated levels of metal pollution compared to areas outside the city like Tegeta. The lower concentrations of Cr might be due to very low solubility and low reactivity of Cr (III) resulting in low Cr mobility in the environment and low toxicity to living organisms. Chromium usually becomes soluble, mobile and toxic to human beings only under oxidation condition within soils where Cr (III) is converted to Cr (VI) (Quarshie et al., 2011).

Concentrations of heavy metals by depth in the selected areas

Table 3 presents the concentration of heavy metals by sampling depths across sites. Overall concentrations of tested elements declined with depth and the decrease was statistically significant for Zn. Zn concentration in the top 0 to 20 cm depth was twice as much as the levels found in the 40-60 cm depth. The percentage declines in Cu and Pb concentrations between these two depths were about 30 and 20%, respectively and 8.6% for Cr. According to Quarshie et al, (2011), low mobility of Cr is probably the reason for much lower difference in the Cr levels between the top and lower soil depths. High concentrations of Zn and Cr on top soils are associated with the presence of roots of various plants at this depth which could increase their concentration through root potential where heavy metals can penetrate and find their way in to soils. Mwegoha and Kihampa, (2010) also found that concentration of Pb, Cr, Cu and Cd, in Msimbazi river in Dar-es-salaam were the highest at the top soil and decreased with depth. This indicates that there is high risk of below ground water contamination when higher concentrations accumulate with time.

Comparison to contaminants limits for heavy metals in soils in Tanzania

Highest concentrations of heavy metals observed in different sites were compared with the contaminant limits for heavy metals in soils of Tanzania as given by the TBS which are 200 mg/kg for Copper, 150 mg/kg for Zinc, 200 mg/kg for Lead, 1 mg/kg for Cadmium and 100 mg/kg for Chromium. The comparison was done to ascertain whether the concentration of heavy metals exceeded permissible limits as per TBS threshold values and understand its associated health risks (Table 4). As noted in this table, levels of heavy metals in the studied soils were much lower than contaminant limits, suggesting that the observed levels posed no health risks to the consumers of vegetables and other food crops grown in the study sites. Jacobi et al. (Un-dated), also highlighted that various assessment conducted in 1994, 1996, 1997, and 1998 by various scientists also found that the contamination level by heavy metals (lead, cadmium and chrome) of water in different streams used for irrigation in Dar es Salaam was within the Tanzanian standards for irrigation water. Regardless of the lower concentration, frequent monitoring of heavy metals is needed as some elements such as Cadmium can accumulate and easily absorbed by plants and enter the food chain. This is because the study by Amend and Mwaisango (1998), established that soils under agriculture contained only

Table 4. Comparison between highest concentrations of heavy metals in sites and the Tanzanian contaminant limits for heavy metals in soils.

Site name	Heavy metal	Highest mean concentration values (mg/kg)	Contaminant Limits for Heavy metals in soils in Tanzania (mg/kg)*	Health risk remarks
Tazara Mchichani	Copper	8.98	200	Low
Tazara Mchichani	Zinc	57.10	150	Low
Tazara Mchichani	Lead	33.70	200	Low
Tegeta, Kigogo Darajani and Temeke Wailers	Cadmium	0.26	1	Low
Tegeta	Chromium	15.29	100	Low

*Source: Tanzania Bureau of Standard (TBS) through Bureau for Industrial Cooperation (BICO), Working paper 2.2, un-dated document.

traces of heavy metals, which posed no risk for farming activities, however, in the immediate vicinity of a major road, the study noted unusually higher concentrations, which might threaten crop production in the future. Often toxicological effects manifest when particular toxic element accumulates in the human body above a certain threshold e.g, the threshold stipulated by the WHO value (Quarshie et al., 2011) or the TBS.

The role of floods in the distribution of heavy metals in the study sites

Ubungo Darajani and Kigogo Darajani, which were the highly flooded sites, had low concentration of heavy metals compared to non-flooded areas, except for Cu and Zn levels in Bunju (Table 2). In contrast, Tazara Mchichani, which is located in a shallow river valley and does not experience frequently floods, had higher values of Cu, Zn and Pb. These results suggest that higher concentration of heavy metals in Tazara mchichani is probably not related to floods but proximity to the industrial areas as explained earlier. It can therefore be concluded that flood seem not to influence heavy metals distribution as flooded areas like Ubungo Darajani, Tazara Mchichani and Kigogo Darajani had similar concentrations of studied metals compared to non flooded areas of Temeke Wailes, Tegeta Darajani and Bunju. It can also be argued that probably the pollution level in flooded sites is very low to cause significant increase of heavy metals in the soil. It might also be due to the reason that all possible sources of heavy metals are well controlled at point sources and therefore do not find their way to downstream water bodies. However, further studies are needed to verify this statement as authors did not sample water during floods or immediately after the flood event. This may underestimate the impacts of floods on heavy metal distribution because only the levels that remained longer in the soils after flood were assessed. Bunju site had lower levels of heavy metals probably because it is an urban agroforestry. The site is far away from the city centre or any industrial site and therefore isolated from any possible source of heavy metals, which might be the reason for lower mean concentrations of such metals.

CONCLUSIONS AND RECOMMENDATIONS

This study evaluated the concentrations of heavy metals in soils from areas used for urban agriculture in Dar-es-Salaam to assess their risks levels for crop production based on the permissible limit from the TBS. It also aimed to establish whether floods had any impact on the distribution of heavy metal concentrations in the soils. Heavy metal concentrations in the soils were below the permissible level established by the TBS, suggesting that heavy metal pollution in these areas does not pose any health risk to humans. Tazara mchichani, however, consistently had highest values of Cu, Zn and Pb concentrations, raising concerns for further studies to curb any possible increase of such heavy metals beyond permissible limits in the future. This will help to monitor changes of heavy metal concentrations in the soil from Tazara Mchichani and trace sources of these elements in order to limit accumulation above the permissible range that may cause health hazard to people.

Heavy metal concentrations in Bunju agroforestry farm, which is located at the outskirt of the Dar-es-Salaam city, were the lowest, possibly because the farm is away from most possible sources of the heavy metal pollution. This suggest that even in less industrialized cities, like Dar-es-Salaam, pollution tends to decrease with distance from the city. Flood seem to have no effect on the distribution of heavy metals as flooded areas had similar or lower levels of heavy metals and nutrients in the soil. This implies that the pollution level in areas where flood water passes is very low to cause significant increase of heavy metals in the soil. However, further studies are necessary which should sample water and soils during floods or immediately after the flood event to monitor heavy metal inputs from flood events. Heavy metal concentrations in sampled area were very low and below the risk levels as recommended by the TBS. It is however, strongly recommended to monitor concentrations of heavy metals in the soils in different areas within the city where vegetables and other food crops are produced. This will help to avoid their accumulation beyond the permissible range above which health hazards to consumers may be significant.

ACKNOWLEDGEMENTS

This work was carried out with the aid of a grant "Global Partners: University of Saskatchewan Small-Grant Program of Research Exchanges" from the International Development Research Centre in partnership with the University of Saskatchewan, Canada and Ardhi University, Tanzania. Permission given to the first author to travel to Canada for this work by ARU is also appreciated. Finally authors are grateful to the anonymous reviewers and the editor for constructive comments on the earlier version of this manuscript.

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