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HEAVY METAL CONCENTRATION IN TOMATOES GROWN IN WASTEWATER IRRIGATED SITES IN DODOMA DISTRICT, TANZANIA

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Abstract

The study was conducted in October 2011 in peri-urban area of Dodoma region, specifically in Dodoma district where wastewater utilization in agriculture was practiced by majority of farmers cultivating different crops close to Waste Stabilization Ponds (WSPs). Heavy metals concentrations were determined in tomato plants irrigated with effluent from WSPs. Findings from this study have shown that as concentration of heavy metals in irrigating water increases, the metal concentrations in plant tissues also increases. The study has also shown that concentrations of heavy metals in roots are much higher compared to the leaves and fruits. Results of the chemical analysis in tomato fruits have demonstrated low concentration of heavy metals compared to the standard given by World Health Organization (WHO) for irrigation sites after the maturation ponds, and higher levels of heavy metals for irrigation site near to the anaerobic pond. On this basis it can be concluded that there is an indication of health risk to the consumers of tomatoes cultivated near to the anaerobic pond.

***Keywords*:** Heavy metals; Wastewater; Tomatoes; Swaswa; Dodoma

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1.0 INTRODUCTION

Use of untreated or partially treated wastewater for irrigation can pose a significant risk to public health and environmental degradation (Blumenthal and Peasey, 2002; Cornish and Kielen, 2004). People who are more likely to face potential risks from the use of wastewater for agriculture are agricultural field workers, consumers and those living near irrigated fields (Buechler *et al*., 2006; WHO, 2006a; b). Several studies have indicated health risks to consumers and people who in one way or the other have close contact with wastewater. Two case studies that examined the impact of untreated wastewater on health in Pakistan indicated higher hookworm infections among farmers and farm workers who used wastewater for irrigation than those who did not (Ensink *et al*., 2004a; b). Vector studies carried out in Haroonabad and Faisalabad in Pakistan (Ensink *et al*., 2004a) revealed that wastewater stabilization ponds and other wastewater bodies favoured the breeding of Anopheles and Culex mosquitoes which contributed to higher risks of vector-borne disease among poor communities that depended on wastewater use for their livelihood.

Wastewater use in agriculture containing a significant level of pollutants may lead to metal accumulation in soils and crops. Human exposure to pollutants applied to soil through wastewater irrigation may take place through food-chain transfer of pollutants via the wastewater through soil, plant, human route and the consumption of grain, vegetables, root crops and fruit (WHO, 2006b). Plants grown in a polluted environment can accumulate the toxic metals at high concentration causing serious risk to human health when consumed (Okoronkwo *et al*., 2005).

The understanding of the behaviour of heavy metal in soil plant system is important due to fact that environmental quality of food production is of major concern in many countries (Chiroma *et al*., 2003). Plant uptake of heavy metals depends on soil condition including pH, the presence of other heavy metals, organic matter content, the application of fertilizers, ploughing and water management (Chen, 1992 cited by WHO, 2006a). Metal concentrations vary in different parts of the plants. Drakatos *et al*. (2000) indicated that heavy metal concentrations in plant tissues are higher in the roots than in the leaves and fruits. Study carried by Rosen (2002) on metal accumulation to different parts of plants revealed that lead (Pb) does not readily accumulate in the fruiting part of vegetable and fruit crops such as beans, tomatoes and apples. The study conducted by Abdullahi *et al*. (2008) on the concentration of trace metals (Cd, Cr and Pb) in tomatoes and onions irrigated with polluted water of river Challawa, northern Nigeria indicated that both tomatoes and onions (exposed) had higher levels of the trace metals than the values recommended by Food and Agriculture Organization (FAO).

Swaswa area which is found in Dodoma district, Dodoma region in Tanzania is becoming famous for production of vegetables and crops which are consumed by urban residence. Effluents from WSPs located in Swaswa area are used to irrigate different crops cultivated close to WSPs. Recently, there has been more concern on the health of consumers of the produce coming from Swaswa area. Currently, there is no information on the extent of contamination in plants irrigated with wastewater in peri-urban areas of Tanzania and specifically in Dodoma district. The objective of this study is to determine the concentration of heavy metal in tomato plant grown in wastewater irrigated field and investigate health risks to consumers.

2.0 Materials and Methods

2.1 Study area

The study was conducted in peri-urban area of Dodoma region, specifically in Dodoma district in Swaswa area where Waste Stabilization Ponds (WSPs) are located. Dodoma region is located in the central plateau of Tanzania extending between latitude 4^o and $7^o30'$ to the South and between longitude 35° and 37° to the East (URT, 1997). The region lies at about 1040 meters above sea level. Dodoma has a dry savannah type of climate that is characterized by seasonal and unreliable rains, with a long dry spell from late April to early December and a short wet season from early December to the end of April (URT, 1997). The average precipitation is between 500mm to 700mm per annum and in Dodoma district in particular average rainfall is 570mm (URT, 2008).

2.2 Sample collection

Tomato samples were collected from wastewater irrigated gardens (Swaswa West located about 100m from the exit point in maturation pond, labeled (D) and Swaswa North located about 1200m from maturation pond, labeled (E)) and non wastewater irrigated garden (Swaswa West, labeled (A) located about 50m adjacent to the anaerobic pond) in a sterile sampling glass bottles separating the edible parts (fruit) from the non-edible parts (roots, stems and leaves) for heavy metal concentration (Figure 1). The separation of vegetables into edible and non-edible parts (Samuel *at al*., 2008) is to establish the trends of heavy metal uptake from the soil to the roots/stems/ leaves and to the fruit of the vegetable. The samples were collected using a zigzag paths (zigzag sampling) to achieve randomness from each garden (Mapanda *et al*., 2005). Collected samples were immediately packed in a cool box with ice packs. The samples were moved to the laboratory within 5h of their collection.

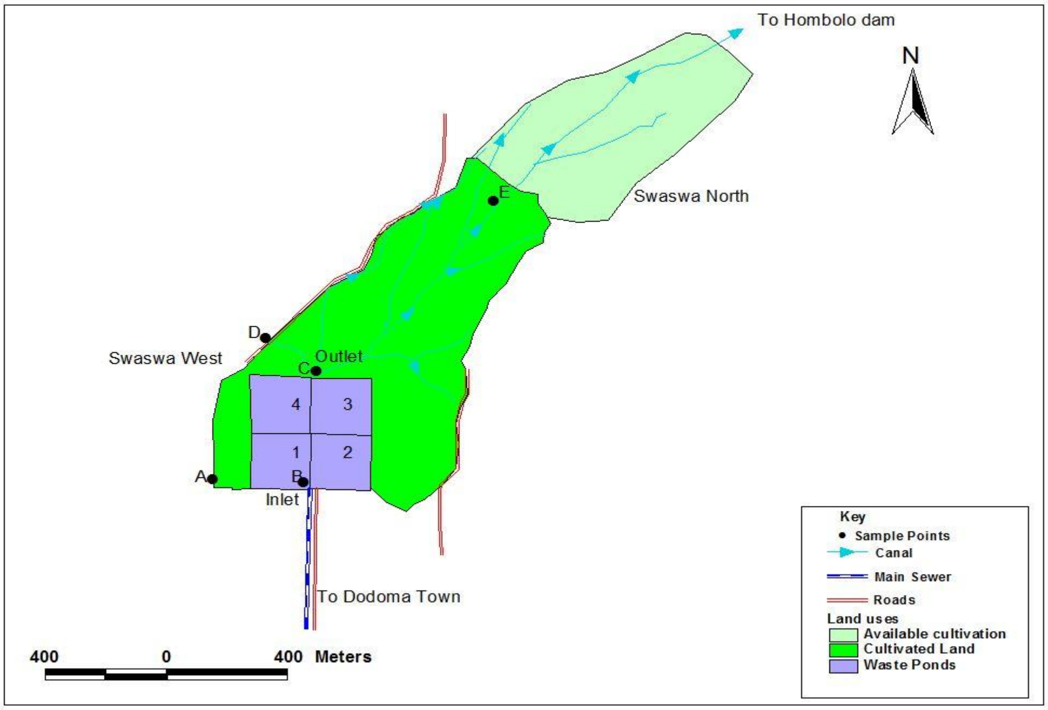

Figure 1. Sketch map showing water, sediments and tomato sampling points in Swaswa area, Dodoma, Tanzania.

Samples of plants were collected, stored in a cool box with packed ice and were transported to the Southern and Eastern Africa Mineral Centre (SEAMIC) laboratory in Dar es Salaam, Tanzania for determination of concentration of heavy metals which include Mercury (Hg), Lead (Pb), Zinc (Zn), Chromium (Cr) and Cadmium (Cd).

2.3 Heavy metal analysis in plant

Vegetable samples (both edible and non-edible parts) were prepared for the analysis of heavy metals (Hg, Pb, Zn, Cr and Cd) concentration (Samuel *at al*., 2008). The raw samples were thoroughly washed to remove all adhered soil particles, initially with raw water and then with distilled water. The samples were then cut into small pieces and then dried in the oven at 70^{o}C. The dried samples were ground in warm condition and passed through 1mm sieve. Well mixed samples of 1.0g each were taken into Teflon beaker. A mixture of 5ml concentrated nitric acid and 5ml perchloric acid was then added. The solution in the beaker was digested on low heat using hot plate for 15min at 70^{o}C until light colored solution was obtained. The digest was allowed to cool. The digested sample was dissolved into 2ml concentrated Nitric acid and then diluted to 50ml with deionized water. Samples were then analyzed for Hg, Pb, Zn, Cr and Cd using a flame atomic absorption spectrophotometer (Inductively Coupled Plasma (ICP-OES) ULTIMA 2 HORIBA JOBIC YVON, France).

2.4 Comparison of the analysed heavy metal levels with total daily intake

The total daily intake (TDI) for total mercury, lead, chromium and cadmium are 0.002, 0.0035, 0.00005 and 0.001 mg/kg body weight, respectively (WHO, 2008). According to Hassan and Ahmed (2002) the daily intake of green vegetable is considered to be 200g/person/day which is recommended amount from nutritional point of view. Tomato consumption in Dodoma urban and peri-urban community is 1-2 times a day and 7 days a week. This assumption was based on the information collected from women who had the responsibility of preparing meals in their households.

Generally, 1kg of tomato was used to prepare four different meals in a household of 2-4 people. Based on this information, the study assumed that consumption of tomato in the study area was 0.125kg/person/day. An average body weight for an adult was considered as 60kg. The maximum acceptable residue levels (MARL) were calculated from TDI values using the following relationship:

$$MARL = \frac{TDI\ (mg/kg\ body\ weight) \times Body\ weight\ (kg)}{Amount\ of\ tomato\ consumed\ per\ day\ (kg)} \qquad \ldots\ldots 1$$

Health risk to consumers of tomato with different levels of heavy metals was investigated by comparing the maximum concentrations of heavy metals that were detected in tomato (fruit) samples with the MARL computed from Equation 1.

3.0 Results and Discussion

3. 1 Heavy metal concentrations in tomato plants

Table 1 shows heavy metal concentrations in tomato plants grown in Swaswa area in Dodoma peri-urban areas in Tanzania. The results show that concentrations of metals in plant tissues in Swaswa West (A) were higher compared to Swaswa West (D) and Swaswa North (E). These findings suggest that as the concentrations of heavy metal in irrigation water increases (Table 1), the heavy metal concentrations in plant tissues also increases (WHO, 2006).

Results from Table 1 also show that, in all three irrigation sites, Hg concentration in leaves and fruits were BDL. Furthermore, concentrations of selected heavy metals in the roots were higher than that in the leaves and fruits. No big variations were observed between metal concentrations in the roots and stem. These findings suggest that metal concentrations in plant tissues are higher in the roots and stem than in the leaves and fruits as reported previously by Drakatos *et al.* (2000). This suggests that root crops irrigated with wastewater are more likely to have more concentration of heavy metals thus putting consumers at health risk.

The trend of occurrence of the heavy metal concentrations in the tomato samples from Swaswa West (A), Swaswa West (D) and Swaswa North (E) with exceptional of Zn is in the order of Pb > Cr > Cd. This trend suggests that tomatoes have higher concentrations of Pb and Cr than Cd. These results support the findings by Abdullahi *et al*. (2008) and Audu and Lawal (2005) that plant samples have higher concentrations of Pb and Cr than Cd.

Table 1: Heavy metal levels (mg/kg) in tomatoes grown in Swaswa irrigated Sites in Dodoma peri-urban areas in Tanzania

Analyte	Swaswa West (A)				Swaswa West (D)				Swaswa North (E)			
	Rts	**Stm**	**Lves**	**Frt**	**Rts**	**Stm**	**Lves**	**Frt**	**Rts**	**Stm**	**Lves**	**Frt**
Hg	0.15	BDL	BDL	BDL	0.01	0.02	BDL	BDL	BDL	BDL	BDL	BDL
Pb	7.26	11.03	1.94	2.87	3.04	1.79	1.36	1.02	3.10	3.43	1.94	1.84
Zn	8.47	9.50	4.58	5.33	6.50	6.66	2.93	1.77	2.95	2.78	1.48	1.13
Cr	8.73	2.48	0.55	0.74	3.25	1.18	0.60	0.19	1.09	0.86	0.12	0.09
Cd	0.70	0.59	0.44	0.67	0.31	0.25	0.27	0.15	0.29	0.25	0.19	0.11

Note: **Rts** means Roots, **Stm** means Stem, **Lves** means Leaves and **Frt** means Fruit

3.2 Heavy metals in tomatoes and its implications to human health

The TDI for heavy metal levels are shown in Table 2. The levels detected in tomatoes cultivated in Swaswa West (D) and Swaswa North (E) was below the maximum acceptable residual limit (MARL). This finding suggests that there is no indication of health risks to consumers of tomatoes irrigated with wastewater after the maturation pond. The results also indicate that the levels detected in tomatoes cultivated in Swaswa West (A) were above the MARL. This finding suggests that there is indication of health risks to the consumers of tomatoes grown close to the anaerobic pond through the food-chain transfer of pollutants (WHO, 2006). A plausible explanation is that in the system of WSPs, anaerobic pond is the source of pollutants and therefore through seepage the source of irrigation water close to the first pond can easily be polluted.

Table 2: Maximum levels detected, tolerable daily intake (TDI) and maximum acceptable residual levels (MARL) for heavy metal levels detected in tomatoes in Swaswa area, Dodoma, Tanzania

Name of site	Trace metal	Maximum levels detected(mg/kg fresh weight)	TDI (mg/kg body weight) (WHO, 2008)	[a]MARL (mg/kg fresh weight)
Swaswa West (A)	Hg	BDL	0.002	-
	Pb	2.87	0.0035	1.68
	Cd	0.67	0.001	0.48
Swaswa West (D)	Hg	BDL	0.002	-
	Pb	1.02	0.0035	1.68
	Cd	0.15	0.001	0.48
Swaswa North (E)	Hg	BDL	0.002	-
	Pb	1.48	0.0035	1.68
	Cd	0.11	0.001	0.48

Note: No health based guideline value has been proposed for Zn and Cr

[a]MARL calculated from TDI as $MARL = \frac{\text{TDI (mg/kg body weight) x Body weight (kg)}}{\text{Amount of tomato consumed per day (kg)}}$

4.0 Conclusions and Recommendation

Concentrations of plant tissues depend on the type of water used for irrigation. The findings of the study have demonstrated that as concentration of heavy metals in irrigating water increases, the metal concentrations in plant tissues also increase. Furthermore, concentrations of heavy metals in roots were found to be much higher compared to the leaves and fruits. Results of the chemical analysis in tomatoes have demonstrated low concentration of heavy metals compared to the recommended values by WHO (2006) for irrigation sites after the maturation ponds, and higher levels of heavy metals for irrigation site near to the anaerobic pond. On this basis it can be concluded that there is no health risks to consumers of tomatoes cultivated after the maturation pond.

Since the study did not capture information concerning the types and number of different pathogens in wastewater used for irrigation which can be used to quantify risk, it is recommended that, more research on microbial analysis be carried out to establish evidence of health effects associated with the use of wastewater in agriculture from infectious agents.

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