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ORIGINAL PAPER

Heavy metals contamination in soils and selected edible parts of free-range local chicken

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Abstract A study was carried out to determine the levels of heavy metals [(arsenic (As), mercury (Hg), cadmium (Cd) and lead (Pb)] contamination in soils and edible parts of free-range local chicken (liver, muscle tissues and abdominal fat) collected randomly in three locations viz Tabata, Kigogo and Vingunguti located in Dar es Salaam city, Tanzania. Concentration of Pb in soils ranged from 5.304 to 7.529, Cd from 0.046 to 0.055, Hg from 0.034 to 0.060 and As from 0.239 to 0.329 ppm, respectively. Lead concentration in soils differed significantly ($P \leq 0.05$) between locations. Differences in soil concentration of As, Hg and Cd between locations were not significant ($P > 0.05$). Heavy metal concentration in chicken parts differed significantly between locations ($P \leq 0.05$). High lead concentration in chicken parts was registered in samples collected at Tabata than at Kigogo and Vingunguti. As and Cd concentration in soil and that in liver and Pb concentration in soil and that in muscle tissues were positive and significant correlated [($P \leq 0.001$) and ($P \leq 0.05$)], respectively. Negative significant ($P \leq 0.05$) correlation was observed between Hg concentration in soils and that in liver and between As concentration in soils and Hg concentration in muscle tissues. Results have shown that heavy metals contaminated in soils may find route into different tissues and organs parts of free-range local chicken; a health concern, hence, calls for safe disposal of industrial and domestic potential sources of heavy metal contamination in soils.

Keywords Liver · Abdominal fats · Muscle tissues · Soil contamination

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Introduction

Food is usually the main source of human exposure to heavy metals. Heavy metals are considered to pose serious chemical health hazards to human and animals (Lars 2003). Heavy metals from man-made pollution sources are continuously released into aquatic and terrestrial ecosystems; and therefore, the concern about the effect of anthropogenic pollution on the ecosystems is growing. Contamination with heavy metals is a serious threat because of their toxicity, bioaccumulation and biomagnifications in the food chain (Demirezen and Uruc 2006). In Tanzania, and particularly in Dar es Salaam city, urban agriculture has been a normal practice along various river banks. These river/streams have been reported to be highly polluted by toxic chemicals from industries, which discharge wastewater untreated into receiving waters along the Msimbazi River valley (Mwegoha and Kihampa 2010). Unlike many other pollutants in the environment, heavy metals are non-biodegradable (Kaewsarn and Yu 2001). In nature, animals are subjected to multiple contamination sources due to their feeding behavior, as such they are considered as good integrators of environmental contaminations and good subjects for examination of pollution and its impacts on the population (Trust et al. 2000). Poultry in free range and small farm flock results in uncontrolled access to all sources of environmental pollutants since birds might accumulate elements not only from polluted soils, water, plants and geohelminths but also from various non-edible wastes and substances containing heavy metal compounds (Van Emous and Fiks-Van-Niekerk 2004). Meluzzi and Simincini (2005) reported that free-range poultry are exposed to heavy metal contamination due to their habits of fetching feeds almost everywhere even in highly contaminated domestic and industrial damping waste disposal areas.

Food chain contamination by heavy metals has become a burning issue in recent years because of their potential accumulation in biosystems through contaminated water, soil and air (Rajesh et al. 2004). Heavy metals accumulate in the organs (like kidney, liver, spleen, abdominal fats and muscles) of chicken due to consumption of feeds contaminated overtime, and once human beings consume these contaminated organs of chicken, the heavy metals will then accumulate in different organs of their bodies. The longer the exposure to heavy metals the higher the bioaccumulation in the body (Chan et al. 2003).

Collapsed sewer infrastructure and the disposal of industrial liquid wastes lead to wastewater, which may contain heavy metals and pathogenic microbes, find their way to the soils and free-range local chicken feeding areas. Consumption of local chicken has recently increased due to consumers awareness on the safety of edible parts of free-range local chicken compared to that of broilers, layers as well as red meat (Van-Overmeire et al. 2006). Many heavy metals can be very toxic and thus may threaten the health of animals (Tandon et al. 2003). Remediation of contaminated soils and water especially with heavy metals has received considerable attention in recent years, and technologies using plants and filtration have been developed and used to remove contaminants from polluted soils and water (Raskin et al. 1997; Garbisu and Alkorta 2001).

Several studies have been conducted to investigate heavy metal levels in environmental samples, as well as heavy metal accumulation and effects on organisms, and factors affecting their accumulation by various organisms. However, no studies have been carried out to correlate heavy metal concentration in soil and edible parts of free local chicken. Hence, this study aims at investigating whether there is relationship between the levels of heavy metals present in the soils and the amount found in local chicken feeding in these environments.

The research was carried out in January 2011 to December 2011 in selected locations of Dar es Salaam city followed by laboratory analyses carried out at the Seamic laboratory, Kunduchi, Dar es Salaam, Tanzania.

Materials and methods

Free-range local chicken of the age of 18 months were collected from three locations (Kigogo, Tabata, Vingunguti) of Dar es Salaam city in Tanzania. The sex of these animals was not taken into consideration during sampling, and non-free-range local chicken was excluded in this study.

Sample collection

In each location, 15 sample plots (each plot representing a farmer) 0.5 km apart were demarcated. Farmers with flock sizes ranging between 10 and 30 free-range local chicken were randomly identified from each location. The age of the chicken in the study area ranged from 12 to 18 months. In each location, chicken of age 18 months were sampled. A total of 90 free-range local chickens were collected randomly from the identified farmers for all three wards (two replicate chicken per farmer × 15 farmers × 3 locations = 90 chicken) viz. Tabata (30), Kigogo (30) and Vingunguti (30) chicken. Similarly, a total of 90 top surface soil samples were collected from areas where the free-range local chicken were collected (two replicate soil samples per farmer × 15 farmers × 3 location = 90 soil samples). Top 10 cm soil samples of about 500 g each were packed in polythene bags and transported to the laboratory for analysis. All samples were collected in the same day to avoid variations.

Sample preparation

Chicken were slaughtered in batches and stored in cool box; samples of liver, abdominal fat and muscle tissue were collected from each of the 90 free-range local chickens, which were slaughtered, making a total of 270 samples. All samples were kept in dematerialized polyethylene sealable sample bags and kept in cool box and transported to Seamic laboratory, Kunduchi, Dar es Salaam, Tanzania for analysis.

Drying and ashing of the edible parts

Ten gram samples each of liver, muscles and abdominal fat of slaughtered free-range local chicken, were homogenized by using mortar and pestle, and then five grams of homogenized material were placed into 50-ml quartz crucibles and dried in an oven set at 125 ± 15 °C for 2 h. Reference standard materials viz. a bovine liver (NBS SRH), a bovine muscle (BCR-278R) and a bovine fat (NBS FTN 276F), obtained from SIGMA Chemical Company, USA were included as quality control. The dried samples of abdominal fat were grounded using mortar and pestle to form paste and then returned back into crucibles. Liver and muscle tissues were ashed in a muffle furnace set at 550 ± 20 °C for 24 h (instead of 12 h), in order to enhance ashing process due to high moisture content of liver and muscle tissues. Ashed samples were removed from the oven and cooled to room temperature (28 ± 5 °C).

Digestion of edible parts

The method described by Vos et al. (1991) and Gonzalez-Weller et al. (2006) was adopted in the extraction of metals from edible parts. The ashed samples of liver and muscle tissues were mixed with 3 ml of 3 N nitric acid and dried on a hot plate at 120 ± 15 °C for half an hour, then placed in muffle furnace and temperature raised to 450 °C for 1 h; this step was repeated three times to get constant weight, from which one gram samples were removed from muffle furnace, cooled to room temperature (28 ± 5 °C) and dissolved in 1 ml of 1 N hydrochloric acid. Two grams of abdominal fat were mixed with 1 ml of 3 N nitric acid; and then, one gram of this mixture was dissolved in 1 ml of 1 N hydrochloric acid. The obtained solutions of liver, muscle tissue and abdominal fat samples were transferred from the crucible to clean test tubes, 1 ml of 0.2 % nitric acid was added to the solutions, and the final solution was diluted with 8 ml of double distilled water to make a total volume of 10 ml, which was then filtered by a 0.5-mm Whatman filter paper to remove coarse particles; the final solutions of 10 ml prepared in duplicate were used to analyze total Cd, Hg, Pb and As. Quality control of analytical measurements was performed using blank samples and the reference materials [a bovine liver (NBS SRH), a bovine muscle (BCR-278R) and a bovine fat (NBS FTN 276F)]. Details of reference materials are as given above.

Preparation and digestion of soil samples

Arsenic, mercury, cadmium and lead contents in soil samples were determined according to AOAC (1995) method number 990.08. Standard reference materials for toxic metals in soils (BCR 146R No. 323), obtained from SIGMA Chemical Company, were used for quality control. Soil samples were dried in hot oven set at 105 ± 15 °C for overnight followed by grinding and sieving using a 2-ml sieve. Two grams of dried fine soil were digested with a mixture of 75 % hydrochloric acid (3 ml) and 25 % nitric acid (1 ml) instead of 50 % nitric acid because soils sample contained little organic materials (sand soil), fine and well dried. The mixture was heated at 95 °C on hot plate for 15 min and left overnight for digestion to take place; the resulted solution was diluted with 6 ml of double distilled water and filtered by using 0.5-mm Whatman paper. The clear solution obtained was used to analyze for Cd, Pb, As and total Hg in duplicate.

Instrument calibration and heavy metal determination

Concentrations of As, Cd and Pb were determined by inductively coupled plasma optical emission spectrophotometer (ULTIMA JY 180 Modern ICP-OES) with detection limit of 0.001 μg/g, and total mercury (T Hg) was analyzed by using automated mercury analyzer (cold vapor technique). The calibration curves for the determination of other heavy metals were prepared using blank and working standard solutions. Lead, cadmium and arsenic were analyzed at their appropriate wavelengths (nm) of 220, 249 and 214, respectively.

Statistical methods

Data were analyzed by using MSTAT-C statistical package, version 2.10 (1995). The experimental design used in this study was factorial design where location being factor A, chicken parts factor B and heavy metals factor C. Duncan's multiple range test was employed to examine which means differed significantly from the others using a significance level of 0.05. Pearson's product-moment correlation coefficient (r) was applied to measure the degree of linear relationship between the level of heavy metal contamination in soils and edible parts of the free-range local chicken at 5 % level of significance.

Results and discussion

Lead concentration in the soils varied significantly between locations ($P \leq 0.05$). Highest lead concentration was recorded in Tabata and lowest in Vingunguti. There was no significant difference ($P > 0.05$) in As, Cd and Hg concentration levels between locations (Table 1). Variations in heavy metal concentration seem to be related to activities and levels of pollution of the areas.

Tabata is heavily populated industrial area. Contamination from these industries and from domestic wastes all

Table 1 Concentrations (μg/g) of heavy metals in soils (dry weight basis)

Location	Arsenic	Mercury	Cadmium	Lead
Tabata	0.239[a]	0.060[a]	0.055[a]	7.529[a]
Kigogo	0.305[a]	0.034[a]	0.046[a]	5.887[b]
Vingunguti	0.329[a]	0.051[a]	0.055[a]	5.304[c]
Means	0.291	0.048	0.052	6.241
CV%	14.12	24.38	26.76	9.03
SE±	0.002	0.031	0.001	0.317

[a,b,c] Means with same letters within the columns do not differ significantly at $P \leq 0.05$ according to Duncan's multiple range test (DMRT)

Table 2 Concentrations (μg/g) of heavy metals in liver of free-range local chicken (dry weight basis)

Location	Arsenic	Mercury	Cadmium	Lead
Tabata	0.086[a]	0.034[a]	0.016[a]	5.624[a]
Kigogo	0.089[a]	0.021[a]	0.029[a]	4.008[c]
Vingunguti	0.095[a]	0.020[a]	0.020[a]	4.497[b]
Means	0.090	0.025	0.022	4.718
CV%	17.110	24.480	26.630	13.690
SE±	0.001	0.0001	0.0001	0.416

[a,b,c] Means with same letters within the columns do not differ significantly at $P \leq 0.05$ according to Duncan's multiple range test (DMRT)

Table 3 Concentrations (μg/g) of heavy metals in muscle tissues of free-range local chicken (dry weight basis)

Locations	Arsenic	Mercury	Cadmium	Lead
Tabata	0.013[a]	0.002[a]	0.005[a]	3.623[a]
Kigogo	0.031[a]	0.007[a]	0.012[a]	1.793[b]
Vingunguti	0.059[a]	0.005[a]	0.005[a]	2.458[c]
Means	0.034	0.005	0.007	2.291
CV%	21.650	25.900	19.020	23.540
SE±	0.001	0.0001	0.0001	0.440

[a,b,c] Means with same letters within the columns do not differ significantly at $P \leq 0.05$ according to Duncan's multiple range test (DMRT)

these could have contributed to high levels of Pb, leaking into the soils at Tabata compared to other locations. Presence of heavy metals in soils collected from industrial and wastes has also been reported by other workers (Nwajei et al. 2007). Car exhaust gases pollution, spilled oils and dust from worn out tires caused by heavy traffic in the study area could also be the source of Pb contamination in soils. However, the concentrations of As, Hg and Pb detected in soils from the present study areas were lower compared to those reported by Mnali (2001) that were in the range of 0.44, 0.10 and 22 μg/g for As, Hg and Pb, respectively, for soils sampled at Lupa gold field in South-West Tanzania. The concentration of some heavy metals in the soils reflected the amounts that were determined in chicken organs. Results in Table 2 show that the free-range local chicken accumulated significantly ($P \leq 0.05$) higher levels of Pb in liver than any other heavy metals (As, Hg, and Cd) probably because of the higher levels of this metal observed in soils from these areas (Table 1). Concentration of As, Hg and Cd in liver was lower and did not differed significantly ($P > 0.05$), suggesting low uptake and accumulation of these metals. Bokori et al. (1995) working on housed birds observed that the concentration of heavy metals was closely related to the levels of heavy metals in feedstuffs, the dose and the duration of heavy metal load.

Table 4 Concentrations (μg/g) of heavy metals in abdominal fat of free-range local chicken (dry weight basis)

Locations	Arsenic	Mercury	Cadmium	Lead
Tabata	0.084[a]	0.029[a]	0.014[a]	5.859[a]
Kigogo	0.062[a]	0.026[a]	0.023[a]	3.514[c]
Vingunguti	0.086[a]	0.022[a]	0.010[a]	3.582[b]
Mean	0.077	0.026	0.016	4.318
CV%	24.490	16.240	25.820	12.640
SE±	0.001	0.001	0.001	0.298

[a,b,c] Means with same letters within the columns do not differ significantly at $P \leq 0.05$ according to Duncan's multiple range test (DMRT)

Table 5 Summary of heavy metals correlations between soil and chicken edible parts (*values with significant correlation)

Metal	As soil	Hg soil	Cd soil	Pb soil
As (liver)	0.811***	0.669*	ns	ns
As (fat)	ns	ns	ns	ns
As muscle	ns	ns	−0.809***	ns
Hg liver	ns	−0.604*	ns	0.652*
Hg fat	ns	ns	ns	ns
Hg muscle	−0.686*	0.686*	ns	ns
Cd liver	ns	ns	0.557*	ns
Cd fat	0.662*	−0.655*	ns	ns
Cd muscle	ns	ns	ns	ns
Pb liver	ns	ns	ns	−0.903***
Pb fat	ns	ns	ns	ns
Pb muscle	ns	ns	ns	0.601*

* $P \leq 0.05$; ** $P \leq 0.01$; *** $P \leq 0.001$ significance level, *ns* non-significant correlation, $n = 9$

Higher levels of lead in liver could be attributed to its slow rate of elimination; hence, harmful levels could accumulate in tissues after prolonged exposure even to low quantities of lead (Barbosa et al. 2005). Similar trend of heavy metal accumulation was observed in muscle tissues and abdominal fat of free-range local chicken (Tables 3, 4).

Presence of heavy metals in meat products collected from polluted areas has also been reported (Viqar-un-Nisa and Mohammad 2005 and Gonzalez-Weller et al. 2006) hence support results of this study. It has been observed that extensive contamination of various foods and beverages with heavy metals as well as their constant and continuous use represent a serious risk to human health, the most dangerous being Pb, Cd and Hg as reported by Nordberg (2006). This author suggested that individuals, those living in areas polluted with such heavy metals and frequently consume local chicken are at higher risk of heavy metal contamination. However, the results of this study have revealed that the concentrations of As and Cd did not exceed the Tanzania Standards (TZS 2007) maximum limit in soils of 1 μg/g for both metals.

Heavy metals with significant correlations between soils and chicken edible parts are shown on Table 5. Concentrations of As, Cd and Pb in soil showed significant and positive correlation with concentration of respective metals in the liver of free-range chicken, suggesting that high levels of these metals in the soil would likely lead to high uptake and accumulation in liver of chicken and vice versa. Contamination of soil with toxic metals thus can cause health hazards to chicken consumers.

Negative significant ($P \leq 0.05$) correlation ($r = -0.604$) was found between Hg concentration in liver and Hg concentration in soils suggesting that the origin of Hg contamination in liver of free-range local chicken could be from other sources other than soil. However, complicated kinetics of metals (absorption, distribution, metabolism, elimination, deposition and excretion) and their mutual interactions is almost impossible to predict metal effects or tissue concentrations based on their concentrations in environment (Lopez Alonso et al. 2004). In the case of free-range local chicken, the most probable heavy metals contamination source of liver, muscles tissue and abdominal fat is the environment (contaminated soil, grit, grass, earthworms and soil-dwelling insects) (Mubofu and Bahemuka1999).

Positive significant ($P \leq 0.05$) correlation ($r = 0.601$) was found between Pb concentration in soil and muscle tissues of free-range local chicken suggesting that probably the origin of Pb in the muscle tissues could be due to contamination of this metal in soil. Negative significant ($P \leq 0.001$) correlations ($r = -0.809$) were found between As concentration in muscle tissue and Cd concentration in soil. The interaction of these metals could likely not be direct as As, and Cd has different binding sites. Arsenic is bound to lipid, while Cd is bound to metal binding protein. Lopez Alonso et al. (2004) observed significant interactions between toxic (As, Cd, Hg and Pb) and nutritional essential elements (Ca, Co, Cr, Cu, Fe, Mn, Mo, Ni, Se, Zn) in the tissues of cattle. Similarly, negative significant ($P \leq 0.05$) correlation ($r = -0.686$) was found between As concentration in the soil and Hg concentration in the muscle tissue. Chan et al. (2003) observed that the uptake of Cd, Cr and Zn by macro alga *Enteromarpha crinita* and subsequent transfer to the marine herbivorous rabbit fish, *sigunus canaliculatus*.

Positive significant ($P \leq 0.05$) correlation ($r = 0.662$) between As concentration in the soil and Cd concentration in abdominal fat was observed. Information on the mechanisms, uptake and accumulation of metals from soils to animal and bird body tissues is limited. Mariam et al. (2004) found that metal interactions can be due to modifications in absorption, metabolism, storage or excretion of one chemical by others, reactions at binding sites or receptors and due to physiological changes caused by other chemicals. Despite metal–metal interactions that occur in animal body, the rate of heavy metal bioaccumulation depends on amount of heavy metals taken and time of exposure.

Conclusion

Heavy metals in soil may find way into food chain. It is concluded that soil of the three selected sites of Dar es Salam city is contaminated with heavy metals. The most concerning conspicuous pollution is found from Pb. The free-range local chicken of these areas tends to accumulate the metals from soil pose health hazard to consumers; community needs to find ways of de-contaminating the area and safe disposal of domestic and industrial wastes.

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