African Journal of Environmental Science and Technology Vol. 4(11), pp. 763-769, November, 2010
Available online at http://www.academicjournals.org/AJEST
ISSN 1991-637X ©2010 Academic Journals

Full Length Research Paper

Heavy metal contamination in agricultural soils and water in Dar es Salaam city, Tanzania

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Accepted 20 September, 2010

Heavy metals in soil and water were determined at four points along Msimbazi River valley in Dar es Salaam city, which is popular for vegetable farming. Results indicated that the concentration of chromium in water ranged from (1.414±0.922) to 0.01 mg/L. Maximum and minimum lead concentrations of 0.113 and 0.083 mg/L were detected. The concentration of copper was generally low at all sites, ranging from (0.013±0.005) to (0.016±0.005) mg/L. The concentration of lead in water throughout the river exceeds the WHO (2004) drinking water limit of 0.01 mg/L, ranging from (0.113±0.104) to (0.083±0.059) mg/L. Cadmium concentration at all sampling points was below detection limit of 0.01 mg/L. Soil analysis indicated that the concentrations of heavy metals are highest at the top soil and decreased with depth. Lead had the highest concentration of (22.85±1.502) mg/kg; which did not exceed the TZS (2003) maximum limit of 200 mg/kg for soils. Chromium had maximum and minimum concentrations of (502.33±150.991) and (174.707±168.278) mg/kg, respectively, with most of samples exceeding the TZS (2003) permissible limit of 200 mg/kg. The maximum and minimum concentrations of copper were (21.073±2.881) and (4.513±1.713) mg/kg, respectively, lower than the TZS (2003) permissible limit of 100 mg/kg. Cadmium concentrations at all sampling points were lower than the permissible concentration of 100 mg/kg in soils (TZS, 2003). The presence of heavy metals in soil and water indicates the potential for pollution transfer from these media to the food chain, especially since this valley is popular for vegetable cultivation.

Key words: Heavy metal, soil, water, pH, dissolved oxygen, Msimbazi River.

INTRODUCTION

Increase in poverty, hunger, lack of formal employment opportunities, demand for food, proximity to markets and availability of cheap resources such as urban organic wastes and wastewater have stimulated the development of diverse of agricultural production systems in and around cities (D'Mello, 2003). Different groups of people are practicing urban agriculture; including those from poor, low, mid and high level of income such as government officials and richer group of people; for leisure, business or investment. The most common urban agricultural activities are community gardens (formal and informal), home gardens, institutional gardens and nurseries managed by schools, hospitals, prisons, and factories (Mubofu and Bahemuka, 1999). Despite the serious environmental and public health effects. One of the associated risks is contamination of crops by heavy goodness of urban agriculture as a source of income and supplement of food supply, the practice is associated with metals and other toxic chemicals. The major entry is through roots and leaves absorbing the chemicals from contaminated soil, water and air (Zurera et al., 1989).

As trace elements, some heavy metals e.g. copper, selenium and zinc are essential to maintain the metabolism of the human body. However, at higher concentrations they can lead to poisoning (Cambra et al., 1999). Prolonged exposure to heavy metals such as cadmium, copper, lead, nickel and zinc can cause deleterious health effects in humans (Reilly, 1991). Metal contamination of garden soils may be widespread in urban areas due to past industrial activity and the use of fossil fuels (Chronopoulos et al., 1997). Total metal concentration in soil does not necessarily correspond with metal bioavailability. The bioavailability of heavy metals depends on a number of physical and chemical

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factors in the soil. These include soil properties e.g. pH, organic matter content, sulfate, carbonate, hydroxide, soil texture and clay content.

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. The level of heavy metal pollution in soils and water in vegetable farms using irrigation water from the river is not adequately articulated. This study therefore aimed at determination of the extent of heavy metal pollution in soils and water, in view of exploring the potential transport and transfer to the food chain through vegetable gardening.

MATERIALS AND METHODS

Description of the study area

This study was conducted along Msimbazi River in Dar es Salaam City, Tanzania (Figure 1). The river receives tributaries that are loaded with effluent discharges from several industries in the area manufacturing batteries, textile, steel, paints, food processing, abattoir, and electrical products. Msimbazi River covers a distance of 45.25 km and receives water from Luhanga tributary (12.15 km), Mambizi, Ubungo sub tributary, Sinza, Zimbire tributary, Kimanga, Kinyenyele and Kwangula sub tributaries (6.5, 20, 19.25, 3.6, 3, 4.35 and 2.25 km respectively). Different activities are carried along the river banks, including irrigation for green vegetable farms, fishing, sand for construction.

Sampling

A total of 56 water samples were collected from seven (7) sampling points (Table 1) between July and October, 2008. These points are Jangwani behind Kajima industrial area where Msimbazi River meets with Luhanga stream (SI), Kigogo commonly known as Msimbazi Valley or SUKITA (S2), Tabata Shule (S3) and Vingunguti (S4). Additional sampling points are located downstream of the mixing point between Luhanga stream and Msimbazi River, Buguruni darajani and another one located downstream of the meeting between the stream emananating from Vingunguti Waste Stabilization Ponds (WSPs) and Msimbazi River.

Collection of water samples

Water samples were collected using 500 mL plastic bottles. The sampling bottles for heavy metal determination were pre-soaked overnight with 10% HCl and rinsed with distilled water and rinsed using river water before sample collection. Sampling bottles for the determination of physicochemical parameters were cleaned and rinsed using distilled water only. Preservation of water samples was done by adding 2 drops of concentrated HNO_3 to each water sample before storage below 4℃ until analyzed.

Collection of soil samples

A total of 24 soil samples were collected at depths of 0 to 15 cm and 15 to 30 cm from four sites, stored in plastic bags and transported to the laboratory for heavy metal extraction and analysis.

Soil sample preparation for heavy metal analysis

The soil samples were oven dried at 105℃ for 24 h, followed by grinding and sieving using 0.18 mm sieve. 0.5 g of dry soil sample was poured into a graduated test tube and mixed with 2 ml of aqua regia 1:3 (1 conc. HCl: 3 conc. HNO_3). The mixture was digested on a hot plate at 95℃ for 1 h and allowed to cool to room temperature. The sample was then diluted to 10 ml using distilled water and left to settle overnight. The supernatant was filtered prior to analysis using AAS as specified in Adams (1991).

Analytical methods

Heavy metals

Analysis of heavy metals in soil and water samples was done using Perking Elmer Analyst 100 Atomic Absorption Spectrophotometer equipped with Perking Elmer HGA 850 Graphite Furnace and Perking Elmer AS 800 Autosampler with a computer interface for operation and readings display, Varian Spectra AAS with $SpectrAA_{55}$.

Conductivity, total dissolved solids and salinity

Conductivity, total dissolved solids (TDS), dissolved oxygen (DO) and salinity were measured using HACH® Sension 156 Conductometer. Temperature and pH were measured using HANNA® meter HI 8424 with pH and temperature probes.

Chemical oxygen demand

Chemical Oxygen Demand (COD) was determined by mixing 1.5 ml of Potassium Dichromate with 3.5 ml concentrated Sulfuric acid in a test tube, followed by addition of 2.5 ml of sample and thorough mixing. The solutions were oven digested for 2 h at 150°C and allowed to cool to room temperature. This was followed by measurement of COD using a portable datalogging Spectrophotometer at wavelength of 600 nm.

Sulfate, nitrate and phosphate concentrations

Sulfate content in water samples was measured by adding Sulfa Ver®4 pill in 25 ml of water sample, followed by vigorous shaking to obtain a uniform mixture which was allowed settle for 5 min for reaction to take place. A spectrophotometer was set and run at a wavelength of 450 nm and blanks were used for calibration and quality check. The same procedure was done for nitrate and phosphate determination, using Nitra Ver®5 Nitrate Reagent for nitrate measurement at a wavelength of 890 nm. For phosphate determination, Phos Ver ®3 Phosphate Reagent was used. All reagents were bought from HACH® Company in Dar es Salaam and parameters were measured in mg/L.

RESULTS AND DISCUSSION

Heavy metal concentration in water

Table 2 shows concentrations of heavy metals in water from various sampling locations. The highest concentration

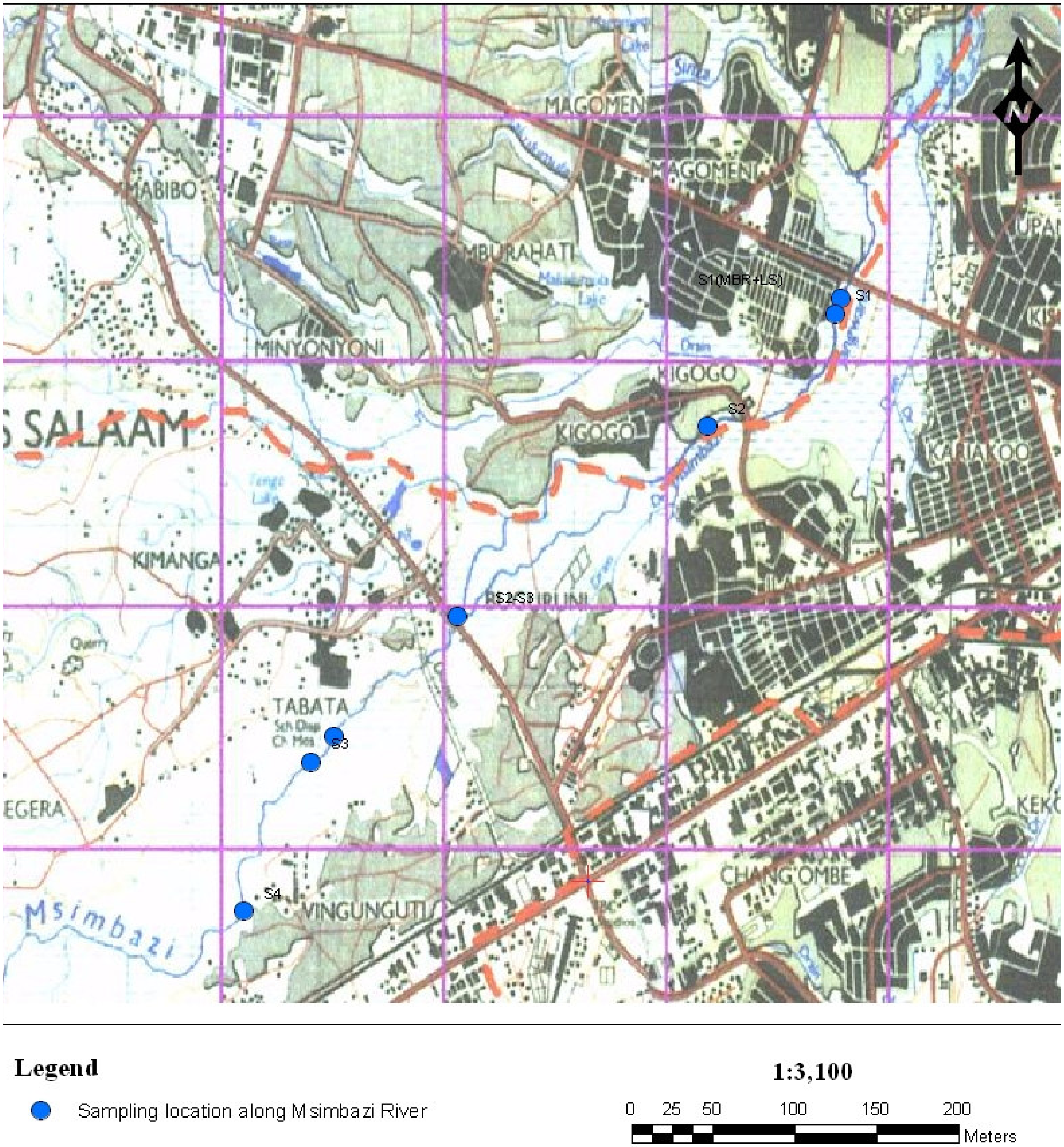

Figure 1. Study area (Msimbazi River) in Dar es Salaam city; SI: Jangwani; S2: Kigogo; S3: Tabata; S4: Vingunguti.

of Chromium (1.414±0.922) mg/L was detected at sampling S2-S3 (Buguruni Darajani). As stated earlier, this point of the river receives effluent streams that are loaded with pollutants from various industries including textile, which are known to contain chromium. The lowest concentration of 0.01 mg/L was detected at sampling S4 located at Vingunguti area, which receives streams from the Vingunguti abattoir and the old Vingunguti dump site

Table 1. Sampling points along Msimbazi river.

Sampling point	Eastings	Northings	Sample collected
S1-1	527184	9244190	Water
S1-2	527181	9244180	Water and soil
S2	527103	9244109	Water and soil
S2-S3	526951	9243990	Water
S3-1	526875	9243914	Water
S3-2	526861	9243898	Water and soil
S4	526820	9243804	Water and soil

Table 2. Heavy metal concentration in water samples.

Sampling location	Concentration (mg/L)			
	Cd	Cr	Cu	Pb
S1-1	bdl	0.658±0.845	0.013±0.005	0.083 ±0.059
S1-2	bdl	1.075±0.969	0.013±0.005	0.083±0.075
S2	bdl	1.093±0.834	0.015±0.006	0.085±0.095
S2-S3	bdl	1.414±0.922	0.016±0.005	0.095±0.093
S3-1	bdl	0.398±0.362	0.016±0.005	0.113±0.104
S3-2	bdl	0.333±0.645	0.013±0.005	0.105±0.052
S4	bdl	0.010	0.013±0.005	0.100±0.064

95% CI, (n=4), S1: Jangwani, S2: Kigogo, S3: Tabata shule, S4: Vingunguti, SD: Standard deviation, bdl: below detection limit, TBS: Tanzania Bureau of Standards, bdl: below detection limit.

with no known source of Chromium contamination. There was no substantial difference in the concentration of copper at various sampling points, ranging from (0.013±0.005) mg/L to (0.016±0.005) mg/L detected at sampling points S2-S3 and S3-1.

The concentration of lead in water throughout the river exceeds the WHO (2004) drinking water limit of 0.01 mg/L. The highest concentration of (0.113±0.104) mg/L was detected at sampling S3-1 where Vingunguti WSP's joins Msimbazi River and the lowest concentration of (0.083±0.059) mg/L at sampling location S1. Maximum concentrations of lead may be attributed to the inflowing channel from Vingunguti WSP's which consists of various wastes from industrial and domestic effluents, including automobile garages and car wash, which discharge mixtures of oil and car washing into the stream leading to Msimbazi River. Such activities may contribute much to lead contamination into Msimbazi River. Cadmium concentration was below detection limit of 0.01 mg/L as indicated in Table 2. However, failure of the AAS machine to detect Cadmium in water samples doesn't mean that it is meeting the recommended drinking water standard of 0.003 mg/l specified in WHO (2004).

Heavy metal concentrations in soil

Heavy metal concentrations in soils are shown in Table 3. Results indicate that for each sampling location, the concentrations are highest at the top soil and decreased with depth. The highest concentration of lead (22.85±1.502) mg/kg was obtained at sampling location S1 and a minimum of (9.623±1.086) mg/kg at sampling point S3. The highest concentration of lead at S1 may be attributed to the contribution of Luhanga stream and polluted channel from the Kigogo garage which utilizes river water for car washing and discharging effluents containing oil into the river. At this point there are also solid wastes dumped into the river which are likely to contain toxic materials including heavy metals. Nevertheless, concentrations of lead in soil at all sampling locations did not exceed the TZS (2003) maximum limit of 200 mg/kg for soils, although may still pose risks to human being as well as the environment.

The highest concentration of (502.33±150.991)mg/kg for chromium was obtained at sampling point S1 and the lowest concentration was (174.707±168.278)mg/kg at sampling point S4, with most of samples exceeding the TZS (2003) limit of 200 mg/kg. Higher concentrations of chromium at sampling point S1may be contributed by Luhanga stream that joins Msimbazi River. Previous unpublished research (Tonya, 2008) has reported massive heavy metal pollution. The maximum concentration of copper of (21.073±2.881) mg/kg was obtained at sampling location S1. This location features plumbing works and manufacture of electroplating

Table 3. Heavy metal concentrations in soils.

Sampling		Concentration (mg/kg dw)			
location	depth (cm)	Pb	Cr	Cu	Cd
S1	0-15	22.853±1.502	502.33±150.991	21.073±2.881	0.623±0.127
	15-30	16.583±4.194	430.85±137.795	14.443±5.237	0.347±0.122
S2	0-15	16.527±0.862	433.817±81.611	15.513±6.0278	0.433±0.0808
	15-30	12.54±2.205	387.313±129.884	13.293±7.095	0.223±0.0289
S3	0-15	16.873±0.613	364.733±135.144	18.397±3.123	0.383±0.293
	15-30	9.623±1.086	265.763±118.618	13.787±3.00	0.363±0.314
S4	0-15	17.973±1.698	231.963±217.617	10.247±9.004	0.19±0.161
	15-30	12.92±0.901	174.707±168.278	4.513±1.713	0.177±0.146

95% CI, S1:Jangwani,S2: Kigogo,S3:Tabata Shule,S4:Vingunguti,SD:Standard deviation, dw: dry weight, n: Sampling frequency, CI: Confidence Interval,, WHO: World Health Organization.

materials. The lowest concentration of copper was (4.513±1.713) mg/kg at sampling location S4. Cadmium concentrations were consistently low at all sampling locations as compared to the rest heavy metals and lower than the recommended concentration of 100 mg/kg in soils (TZS, 2003) The maximum concentration of cadmium was obtained at sampling location S1 with (0.623±0.127) mg/kg at a depth of 0-15 cm and minimum concentration at S4 with (0.177±0.146) mg/kg.

Physicochemical parameters

Generally, water from all sites had high pH levels, which may have caused heavy metal precipitation to the bottom sediments as pointed out by Jorgensen (1994). This phenomenon may hinder heavy metal availability in water. Results in Table 4, shows the maximum DO concentration of (0.99±0.31) mg/L was obtained at sampling point S4 where the channel from Vingunguti WSPs joins Msimbazi River. Minimum DO concentration of (0.22±0.27) mg/L was obtained at Vingunguti site, probably because Vingunguti abattoir discharges its effluents directly into Msimbazi River without pre treatment together with leachate pollution from the nearby old Vingunguti dump. Substantial variation of DO concentration at sampling points S1-1 (0.96±0.57) mg/L, S2 (0.76±0.43) mg/L and S2-S3 (0.77±0.44) mg/L are due to the fact that at point S1-1 the Luhanga stream receives waste streams from different industries and the concentrations varies according to the types of activities upstream from time to time. At sampling S2, there are different domestic wastewater channels discharging effluent into the river. At sampling points S2-S3 there are numerous industries which discharge their wastewater directly into Msimbazi River, consequently leading to DO variations.

Table 4 also shows highest concentration of TDS at sampling point S4, possibly caused by high solids loading in the influent channel from the Vingunguti abattoir into the river. Lowest TDS concentration was obtained at sampling point S1-1 due to dilution effect from the Luhanga stream. TDS are known to be negatively charged and therefore attract more heavy metal ions, reducing their concentrations in water. Results in Table 4 also show variations of conductivity in water samples from different sampling locations along the river. The highest conductivity was (3262.5±94.3) S/cm at sampling location S4 and the lowest conductivity of (1918.8±513.8) S/cm at sampling location S1-2. At sampling S4 the river receives effluents from Vingunguti abattoir. Higher conductivity values indicate higher concentrations of free metal ions in water, which reduces heavy metal concentrations from the River. AAS detects heavy metal atoms and not in ionic forms which are likely to be available in water sampled along Msimbazi River.

Salinity levels also varied at different sampling locations as indicated in Table 4. The highest levels were found at sampling points S4 and S3-1 with salinity value of 1.7‰, and the lowest concentration was obtained at sampling point S1. Results in Table 4 show further that maximum concentration of sulfate was (64.0±16.8) mg/L at sampling point S2-S3 where most of industries located in proximity to this area discharge their effluent into the river. Minimum concentration of (46.0±18.6) mg/L was obtained at sampling location S1-2 featuring a number of automobile garages and local car wash facilities.Principal source of phosphorus in wastewater is agricultural return and land runoff, which contributes to eutrophication of receiving surface water bodies. Maximum concentration of phosphate of (10.6±6.8) mg/L was obtained at sampling location S2. High phosphate concentrations can be connected with storm water runoff from the nearby vegetable farms, which happens to contain phosphates residues from fertilizer application. There are variations of nitrate concentrations at different sampling locations as shown in Table 4. The presence of nitrate in water indicates the presence of fully oxidized organic matter. The highest concentration of NO_3 was obtained at sampling point S4 with a value of (6.2±1.6) mg/L.

Table 4. Physicochemical parameters measured from Msimbazi river water.

Parameter	Mean ± SD							
	S1-1	S1-2	S2	S2-S3	S3-1	S3-2	S4	TBS
Temperature (℃)	26.2±0.7	26.1±0.9	26.2±0.8	26.5±1.0	25.4±1.7	25.2±2.0	25.8±1.9	20-35
pH	8.715±1.02	8.08±0.98	8.6±0.36	8.58±0.45	8.718±0.41	8.425±0.23	8.48±0.165	6.5-8.5
DO (mg/L)	0.96±0.57	0.86±0.28	0.76±0.43	0.77±0.44	0.99±0.31	0.76±0.06	0.22±0.27	
TDS (mg/L)	1053.8±173.6	1414.5±693.8	1213.3±45.3	1356.3±150.9	1526.3±325.9	1246.0±274.9	1643.0±69.2	
EC (S/cm)	2101.5±347.3	1918.8±513.8	2323.5±211.4	2570.0±300.3	3242.5±223.2	2482.5±531.8	3262.5±94.3	
Salinity ‰	1.1.±0.2	1.1±0.1	1.3±0.1	1.3±0.2	1.7±0.1	1.3±0.2	1.7±0.1	
SO_4^{2-} (mg/L)	62.8±7.2	46.0±18.6	51.3±35.8	64.0±16.8	62.8±10.9	56.5±16.4	51.5±22.3	500
PO_4^{2-} (mg/L)	2.9±1.3	7.4±4.4	10.6±6.8	1.9±0.7	2.3±0.9	2.0±0.7	2.4±1.7	6
NO_3^- (mg/L)	1.1±0.5	1.5±1.5	1.2±0.4	1.1±0.1	1.3±0.1	2.3±1.3	6.2±1.6	20
COD mg/L)	634±266	487±191	574±248	511±274	568±325	637±353	654±1353	60

95 % CI, (n=4)S1-1: Jangwani (Luhanga stream joins Msimbazi River), S1-2: Jangwani. S2: Kigogo, S2-S3: Buguruni Darajani,, S3-1: Vingunguti WSP"s joins Msimbazi River, S3-2 Tabata Shule,S4:Vingunguti, SD: Standard deviation,, DO: Dissolved Oxygen, TDS: Total Dissolved Solids, EC :Electric Conductivity, TBS: Tanzania Bureau of Standards.

Minimum concentration of 1.1 mg/L was found at sampling point S1-1 where Luhanga stream joins Msimbazi River. There is no substantial difference between NO_3 concentrations between sites S1-1 to S3-3. Sharp increase at S4, indicates that wastewater from the abattoir is rich in nitrate. The COD test aimed at determining the amount of organic matter present in industrial wastewater. Results in Table 4 show variability of COD concentrations varies from one sampling point to another. Nevertheless, a sharp increase of COD concentration at sampling S4 is probably attributed to inflows that have strong organic loading from Vingunguti abattoir.

Conclusions

The results from water samples showed that the concentration of heavy metals in water and soil from the majority of sampling locations exceeded permissible set by WHO (2004) and Tanzania local standards (TZS, 2003) for drinking water and soils, respectively. Variations in heavy metal concentrations in water and soil are a consequence of a wide range of human activities in the river valley. Much precaution has to be taken especially on the use of water from Msimbazi River as may pose risks to the users. Msimbazi River is mainly used as a major source of water for vegetable irrigation. Investigation on the implication of these high concentrations of heavy metals in water and soil on uptake by irrigated vegetables is highly needed.

ACKNOWLEDGMENTS

The authors wish to acknowledge the work done by Mr. Leonard Sibomana of Ardhi University during data collection and organization.

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