Scientific Research and Essays Vol. 5(16), pp. 2143-2147, 18 August, 2010
Available online at http://www.academicjournals.org/SRE
ISSN 1992-2248 ©2010 Academic Journals

Full Length Research Paper

Heavy metal concentrations in soils and leachetes of Mtoni dumpsite bordering the Indian Ocean in Dar es Salaam, Tanzania

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Accepted 4 June, 2010

Concentrations of heavy metals in soils and leachetes in the closed coastal dumpsite of Mtoni, Dar es Salaam, Tanzania were determined using Atomic Absorption Spectrophotometer. Mean concentrations of leachetes in mg/L were in the following order: Cr > Ni> Pb> As> Cd whereas, concentrations of As and Cr in the soil samples were above the established contaminant limits of Tanzania Standard Soil Quality. The concentration of Ni was low. Soil samples at 10 m from the edge of the dumpsite showed higher concentrations of Cd and Pb compared to the established national contamination limit. Based on this observation we recommend awareness creation to farmers depending on the area for vegetable production on the need to relocate their activities to at least 200 m away from the edge of the dumpsite. Moreover, alternative income generating activities for farmers should be considered by the communities and the municipal authorities in order to reduce health hazards that may affect urban smallholder farmers depending on the dumpsite areas for agricultural production.

Key words: Bio-accumulation, marine organisms, pollutants, Tanzania, toxic elements, vegetable production.

INTRODUCTION

There is no doubt that soil is a primary recipient of solid waste and that millions of tons of these wastes from a variety of sources: Industrial, domestic and agricultural, find their way into the soil (Nyles and Ray, 1999). In literature, it is well explained that Municipal wastes increase the nitrogen, pH, cation exchange capacity, percentage base saturation and organic matter of the receiving soils. Furthermore, excessive waste in soil can increase heavy metal concentration in the soil and underground water that may have harmful effects on soils, crop and human health (Nyle and Ray, 1999; Smith et al., 1996; Okoronkwo et al., 2006). Leachetes flowing to the ocean cause contamination which may result into affecting the aquatic biodiversity.

Soils are central to the sustainability of our ecosystems, performing essential functions such as nutrient cycling to support plant growth, the attenuation and transformation of potentially toxic compounds and elements and the maintenance of biodiversity. As reported in Ebong et al. (2008), leachetes from refuse dumpsite constitute a source of heavy metals pollution to both soil and aquatic environments. Biosphere pollution by chemicals and heavy metals such as cadmium, nickel, zinc, lead, copper and others has been accelerated dramatically during the last few decades due to mining, smelting, manufacturing, use of agricultural fertilizers, pesticides, municipal wastes, traffic emissions, industrial effluents and industrial chemicals (Sial et al., 2006).

Higher concentrations of heavy metals in soils have been reported to inhibit plant growth, nutrient uptake and physiological and metabolic processes. This also results in chlorosis, damage to root tips, reduced water and nutrient uptake and damage to enzymes (Baisberg-Påhlsson, 1989; Sanità di Toppi and Gabbrielli, 1999). Heavy metals, like other environmental stressors, also induce antioxidant enzyme activities increased in plants (Lannelli et al., 2002). These toxic ions may remain in soil or leach out and may contaminate ground water along with the soil itself and finally enter the food chain and cause health hazard in animals and plants. As reported in the literature (Bay et al., 2003; Sadiq, 2002), rapid urbanization, industrialization and population growth are the major causes of stress on the environment leading to problems like human health problems, eutrophication and

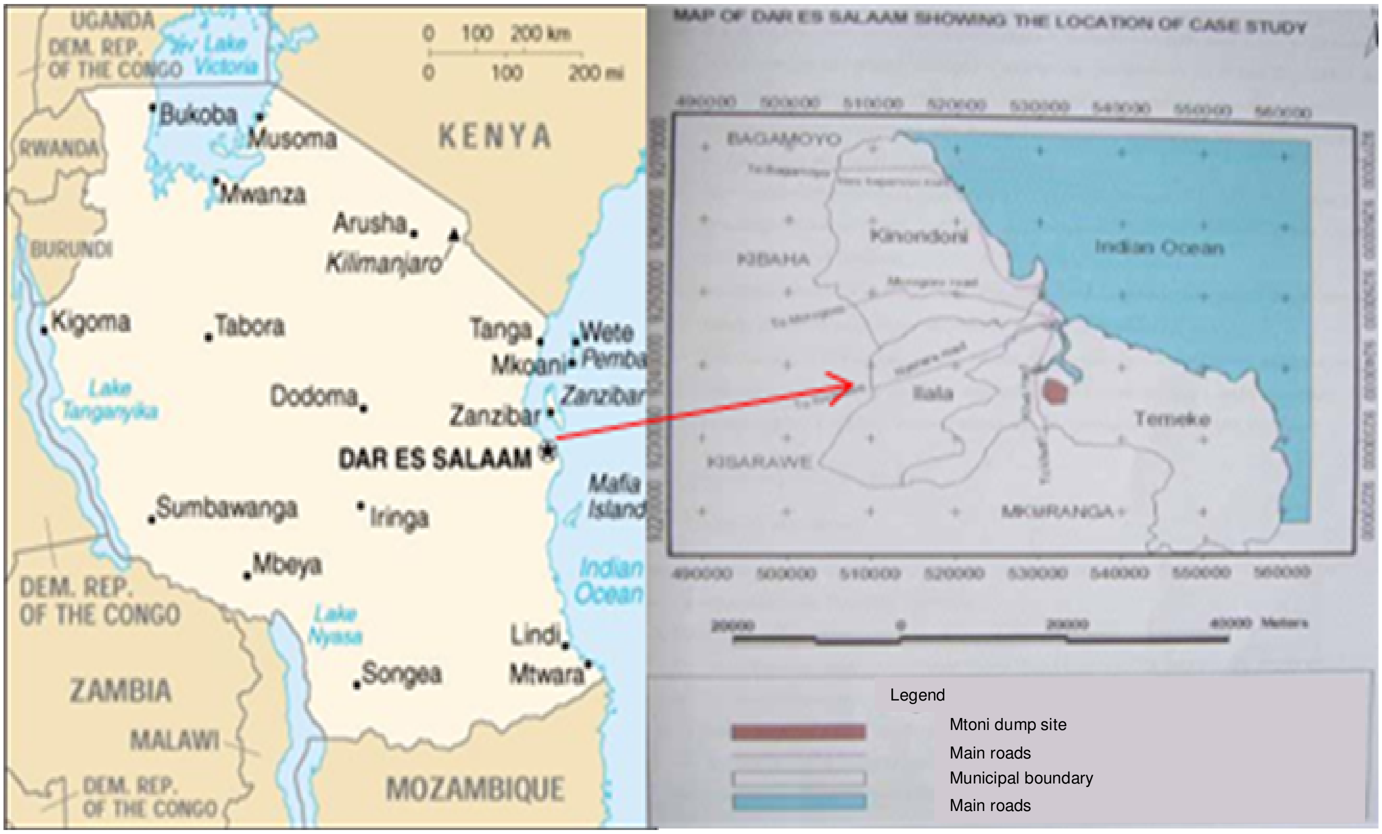

Figure 1. Map of Tanzania showing Dar es Salaam and the case study site.

fish death, coral reef destruction, biodiversity loss, ozone layer depletion and climate changes.

As it is in most cases, soils in municipal waste dumpsites commonly serve as fertile ground for the cultivation of a variety of fruits and leafy vegetables and the soils are also used as 'compost' by farmers with little regard to the probable health hazards the heavy metal contents of such soils may pose (Amusan et al., 2005).

A similar problem exists at the closed dumpsite at Mtoni, which is located centrally within Dar es Salaam city boundaries where a 10 years' worth of refuse is left to produce streams of poisonous leachetes which runs unchecked into the river and hence to the Indian Ocean situated only a few meters away form the edge of this dumpsite. Dearth of information regarding the levels of heavy metals in the soils and the leachetes flowing to the Indian Ocean from Mtoni dumpsite, suggested the need for this particular study in this area.

MATERIALS AND METHODS

The study site

The present study was carried out in Dar es Salaam region the commercial capital of Tanzania with a population of over 3 million people. The region is located between 6°29'S to 7°30'S and 39°80' E to 39°30' E. Administratively, the region is divided into three districts herewith referred to as municipals. These are Kinondoni, Ilala and Temeke. The city is bordered by the Indian Ocean to the east and surrounded by the Coast Region to the north, south and west (Figure 1). The neighboring areas surrounding the Mtoni waste dumpsite are used for vegetable production such as spinach and tomatoes. This waste dumpsite has been selected as study site due to the fact that it is located in Mtoni estuarine system covered by mangroves. Municipal council allowed dumping of solid waste from Dar es Salaam city in the vicinity and just adjacent to the mangrove stand. During rains, the leachetes finds its way into the stream then to the Indian Ocean posing a health hazard to both marine flora and fauna in the area.

Sample collection and analyses procedure

Soil samples were collected at 0 - 15 cm depth. Four soil samples were collected at each point at 10, 50, 100,150 and 200 m from the edge of the dumpsite towards the areas where more gardens are located in the north direction of the dumpsite. For each sampling point, four samples were thoroughly mixed and one composite soil sample derived for laboratory analysis. Heavy metals in both soils and leachetes samples collected at different points within the boundaries of the Indian Ocean close to the dumpsite were analyzed as described in the literature (Black, 1965; Boln et al., 1976; Okoronkwo et al., 2006). Heavy metals determined from the soils and leachetes include arsenic (As), cadmium (Cd), chromium (Cr), nickel (Ni) and lead (Pb).

Soil samples were dried in an oven at 40°C for 48 h, ground to pass through a 2 mm sieve. Dry ground samples weighing 0.5 g was mixed with 1.5 ml concentrated HCL and 0.5 ml of

Table 1. Statistical data on contents of some heavy metals (mg/l) of leachetes flowing just below dump site, waters used in irrigating vegetables and leachetes flowing to the Indian ocean at Mtoni dumpsite in Dar es Salaam Tanzania.

Location/Heavy metals	pH	As (mg/L)	Cd (mg/L)	Cr (mg/L)	Ni (mg/L)	Pb (mg/L)
Just below the dump	8.9	0.07 ± 0.02	0.04 ± 0.01	4.15 ± 3.51	1.07 ± 1.23	0.94 ± 0.78
Used for watering vegetables	8.5	<0.01± 0.00	<0.001± 0.00	<0.01± 0.00	0.02 ± 0.11	0.05 ± 0.02
Flowing towards the Indian ocean	8.2	0.01 ± 0.00	0.11±0.01	0.07±0.02	0.60 ± 0.03	0.41± 0.08

The values presented in the table are means ± standard deviations.

concentrated HNO_3 in a graduated test tube and digested on a hotplate at 95℃. The digest was cooled to room temperature and diluted with deodorized water to 10 ml. After settling for overnight, samples were ready for analysis using Atomic Absorption Spectrophotometer Model (GBC 906) (USA) in the flame mode.

Leachetes samples were analyzed directly without any filtration or digestion, using the Atomic Absorption Spectrophotometer Model (GBC 906) (USA) in the flame mode. Known standard sample prepared from the metals in distilled water and subjected to the same process as for the samples, so as to determine accuracy and precision of the method used was done as a quality control measure. Analysis of each sample was replicated three times.

For As, the analysis procedure depended entirely on the production of arsenic hydride which was then atomized in a hydride cell of the AAS to give an absorbing population of As atoms. The formation of (AsH_3) depends on the availability of Arsenic in a reducible state, As (V), which is reduced to As (III) by a borohydride reagent. The Hydride vapor obtained was passed through a hydride cell of the HG 3000 system and the absorption signal was determined by the GBC 906 Atomic Absorption Spectrophotometer.

Data analyses

Data generated from the laboratory analysis were analyzed for their descriptive statistics using Statistical Programme for Social Sciences (SPSS) Software Version 11.0.

RESULTS

Contents of heavy metals in leachetes at Mtoni dumpsite

Concentration of heavy metals in leachetes flowing at the edge of the dumpsite, water used for vegetables irrigation, and leachetes flowing to the Indian Ocean are shown in Table 1. The pH of leachetes collected from different points were 8.9 for the leachetes samples collected just below the dumpsite, 8.5 for water used for watering vegetables and 8.2 for the leachetes flowing to the Indian ocean. The leachetes contained high levels of chromium (4.15 ± 3.51 mg/L), nickel (1.07 ± 1.23 mg/L) and lead (0.94 ± 0.78 mg/L) although other heavy metals such as arsenic (0.07 ± 0.02 mg/L) and cadmium (0.04 ± 0.01 mg/L) do exist in the leachetes and their concentration were very low.

Smallholder farmers were observed to be using water mixed with the flowing leachetes from the dumpsite to irrigate vegetables. Concentrations of heavy metals from water samples used in irrigating vegetables in this area were very little (Table 1). Heavy metals for the leachetes flowing to the Indian Ocean from the dumpsite determined, indicated the following concentrations: Nickel (0.60 ± 0.03 mg/L), Pb (0.41 ± 0.08 mg/L), Cd (0.11 ± 0.01 mg/L), Cr (0.07 ± 0.02 mg/L) and As (0.01 ± 0.00 mg/L). This indicates that the flowing leachetes is rich in nickel with less arsenic.

Contents of toxic elements on soils from different distances from Mtoni dumpsite in Dar es Salaam Tanzania

Soils surrounding the dumpsite are loamy sand with mean composition of 81% sand, 11.22% silt and 7.78% clay. Soil samples analyzed for heavy metals at different distances from the dumpsite indicated different concentration levels at different distances (Table 2).

In all the tested heavy metals, their concentrations were higher at the distance of 10 m from the edge of the dumpsite where some vegetable fields are located. Furthermore, results indicate concentration levels of heavy metals to decrease with distance except for nickel.

Heavy metal content from Mtoni dumpsite was compared to that from dormant dumpsites including El-Akader in Jordan (Abu-Rukah and Alkafahi, 2001), Gromono in Norway, Cedar Hill and Kent Highlands in USA, (Hovarth, 1998), Taranrod in Japan (Jeffery et al., 1989) and Olusosun, Nigeria (Ogundiran and Afolabi, 2008). Findings from our study indicate higher concentration of cadmium (0.04 mg/L) in Mtoni dumpsite compared to other dumpsited reported in Table 3. For nickel and chromium, findings from our study shows higher heavy metals concentration to the values obtained in Gronomo in Norway, Taranrod, Japan Kent Highlands in USA and Olusosun, Nigeria (Hovarth, 1998; Ogundiran and Afolabi, 2008). Furthermore; concentrations of Nickel and chromium are lower in the Mtoni dumpsite compared to those obtained in El-Akader in Jordan and Cedal Hill in USA (Abu-Rukah and Alkafahi, 2001; Hovarth, 1998).

DISCUSSION

Contamination levels of heavy metals in the study area

Table 2. Statistical data on contents of some heavy metals (mg/kg) on soils at 10, 50, 100, 150 and 200 m from the edge of Mtoni dump site in Dar es Salaam Tanzania.

Distance (m)	As (mg/kg)	Cd (mg/kg)	Cr (mg/kg)	Ni (mg/kg)	Pb (mg/kg)
10	46.52 ± 41.90	18.90 ± 8.85	332.92 ± 265.58	21.30 ± 6.18	223.80 ± 146.73
50	34.02 ± 0.88	0.01 ± 0.00	244.97 ± 7.12	7.01 ± 1.32	25.19 ± 13.99
100	20.78 ± 3.37	0.01 ± 0.00	179.68 ± 185.95	4.76 ± 1.41	15.17± 1.20
150	18.62 ± 2.04	0.01 ± 0.00	168.17 ± 28.52	4.09 ± 0.10	13.77 ± 2.96
200	13.81 ± 3.46	0.01 ± 0.00	145.29 ± 7.09	4.87 ± 2.49	7.63 ± 0.83

The values presented in the table are means ± standard deviations.

Table 3. Comparisons of heavy metals from the leachetes at Mtoni closed dumpsite with other dormant dumpsites.

Parameter	El-Akader Jodan[a]	Gromono, Norway[b]	Cedar Hill, USA[b]	Kent Highlands, USA[b]	Taranrod, Japan[c]	Olusosun, Nigeria[d]	Mtoni, Dar es Salaam[e]
Pb (mg/L)	0.190	0.004	1.40	20.10	0.015	0.110	0.94
Cd (mg/L)	0.012	0.005	ND	ND	0.033	0.001	0.04
Ni (mg/L)	18	<0. 100	1.200	0.100	0.120	0.070	1.07
Cr (mg/L)	ND	0.023	10.50	0.050	0.170	0.060	4.15

[a]Abu-Rukah and Alkafahi (2001),[b]Hovarth (1998),[c]Jeffery et al. (1989), [d]Ogundiran and Afolabi (2008), [e]This study ND = Not determined.

were compared to the contamination limits described in the Tanzanian Standard Soil Quality (TBS, 2007). Metals compared to the national standards include arsenic, cadmium, chromium, nickel and lead.

Based on the upper limit for soil contaminants in habitats and agriculture (TBS, 2007), arsenic contents in the soils surrounding Mtoni damp site is high. As indicated in Table 2, the determined contents of arsenic in the soil ranged between 13.81 ± 3.46 mg/kg and 46.52 ± 41.90 mg/kg (at 200 m and 10 m from the edge of the dumpsite, respectively). These values are very high compared to the upper limit that has been set for soil contaminant by the Tanzanian Bureau of Standards whose value is 1 mg/kg (TBS, 2007). This therefore indicates that at any point from 10 - 200 m from the edge of the dumpsite soils are highly contaminated with arsenic and this is dangerous to human being. According to Saha et al. (1999) inorganic arsenic is extremely toxic to human beings.

Cadmium contents for soils sampled at different distances from Mtoni dumpsite is only high at 10 m from the edge of the dumpsite when compared to the established limit for Tanzania soil contaminants in habitat and agriculture (TBS, 2007). As indicated in TBS (2007), the value for contaminant limit for cadmium for soils in Tanzanian is 1 mg/kg. Cadmium content at other distances (50, 100, 150 and 200 m) from the edge of the dumpsite was observed to be very low (< 0.01) as indicated in Table 2 when compared to the established National cadmium contaminant limit (TBS, 2007).

Contents of chromium in the soils tested at different distances from the edge of the dumpsite ranged between 145.29 ± 7.09 and 332.92 ± 265.58 which are higher compared to the established limit for soil contaminants in habitat and agriculture for Tanzania. The upper limit for chromium based on the Tanzania Bureau of Standards is 100 mg/kg (TBS, 2007).

Concentrations of nickel in the soils surrounding Mtoni dumpsite at different distances from the edge of the dumpsite were lower compared to the upper limit for nickel established in the Tanzania Standard Soil Quality. Mean concentrations of nickel ranged between 4.09 ± 0.10 and 21.30 ± 6.18mg/Kg which is absolutely lower to the 100 mg/kg as required for soils in Tanzania (TBS, 2007).

Lead concentrations in the soils surrounding Mtoni dumpsite was observed to be only high at 10 m from the edge of the dumpsite when compared to the contaminant limit established in the Tanzania Standard Soil Quality. At 10 m from the edge of the dumpsite, mean concentration was 223.80 ± 146.73 mg/kg which is higher than the 200 mg/kg contaminant limit set for soils in Tanzania (TBS, 2007). Other concentrations measured at 50, 100, 150 and 200 m from the edge of the dumpsite were 25.19 ± 13.99 mg/kg, 15.17 ± 1.20 mg/kg, 13.77 ± 2.96 mg/kg and 7.63 ± 0.83 mg/kg, respectively which are lower than the established contaminant limit of lead for soils in Tanzania. Results from our study indicate high values of lead (0.94 mg/L) for the leachetes just flowing from the closed Mtoni dumpsite compared to those obtained in El-Akader in Jordan, Gronomo in Norway, Taranrod, Japan and Olusosun, Nigeria (Abu-Rukah and Alkafahi, 2001; Ogundiran and Afolabi, 2008) as indicated in Table 4. Furthermore, values obtained from this study are low when compared to the lead concentration determined in two dormant sites of Cedal Hill and Kent Highlands in USA (Hovarth, 1998 in Ogundiran and Afolabi, 2008).

CONCLUSIONS AND RECOMMENDATIONS

In this study, it was observed that soils used for vegetable production around Mtoni dumpsite and leachetes that is used for watering the vegetables and that which is flowing to the Indian Ocean, contain a high concentrations of some heavy metals. Some of these metals are toxic to both fauna and flora. Chemical composition of the soils studied in the area has indicated to vary with distance from the edge of the dumpsite.

As observed in this study, soils close to the edge of the dumpsite contain highly concentrated heavy metals, some of which are toxic to human being. Similarly, the general trend for the leachetes that were observed to flow from the edge of the dumpsite were heavily contaminated by some heavy toxic elements compared to the ones that are used for watering vegetables and those flowing to the Mtoni Estuary towards the Indian Ocean. Based on the results from this study the following recommendations are given:

1. Awareness to farmers depending on the area for vegetable production on the need to shift from raising their vegetables at 10 m from the edge to at least 200 m away from the edge of the dumpsite is recommended. This may be a useful idea for reducing health risks to the farmers themselves and to other users of the vegetables that are produced in this area.
2. Alternative income generating activities for farmers who depend on the soils from this area for vegetable production is needed. This will help to reduce the dependence of the plots surrounding the dumpsite as the sole source of the income to the people in the area and hence reduce the use of these soils in the production of vegetables.
3. Location of any dumpsite should take into consideration the effects of the heavy metals that may be produced and enter the food chain, dumpsite should be located in the areas that can have no direct link with human activities and also direct link to the marine biodiversity.
4. Studies on the concentration of toxic elements in the plants and marine organisms in the areas surrounding the dumpsites in the Indian Ocean to be carried out to determine the effects of the toxic elements from the dumpsites to the biodiversity both fauna and flora.

ACKNOWLEDGEMENTS

The author is grateful to; the Western Indian Ocean Marine Science Association (WIOMSA) for its financial assistance and the technicians in the Laboratory of the School of Environmental Sciences and Technology (SEST) of Ardhi University for their assistance in the sample analysis.

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