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Full Length Research Paper

Heavy metal contamination of land and water around the Nairobi City Dandora dumpsite, Kenya

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The Dandora waste dumpsite is a major disposal site of waste generated from various activities in Nairobi city. There has been concern over the health implications of this dumpsite from numerous quarters. A study was done to determine the negative impact to the environment attributed to the Dandora dumpsite and to recommend corrective measures. Environmental samples (soil and water) were taken at different points and analyzed to determine contents and concentrations of elements. High levels of toxic heavy metals (cadmium, lead and mercury) were noted in both soil and water samples. Heavy metals are known to have toxic properties, leading to adverse effects on human and ecosystem health even in small doses. The results obtained indicate high potential risk both to the environment and human health the dumpsite. There is need for measures to be instituted for proper waste management to minimize environmental pollution that is a risk to human health. Creating awareness on activities of the rehabilitation and restoration of the Nairobi River basin is very critical. This would enhance a clean and healthy environment. The Nairobi City Council should develop and adopt a more efficient Integrated Solid Waste Management to help in maximizing resource efficiency

Keywords: Heavy mental, waste, land, water, Dandora dumpsite Nairobi, Kenya.

INTRODUCTION

One of Africa's largest waste dumps, the Dandora Municipal Dumping Site in Nairobi, is a serious threat to people living nearby and the city's environment generally, (UNEP, 2007). It is impossible to control unregulated recovery of material through scavengers, fires, Leachate and waste disposal in the site. The dumpsite is a major dumping site located at the East of Nairobi in Kenya. The dumpsite is about 8 kilometers away from the city centre. The dump site stands on a 32 acre piece of land overlooking the informal settlements of Dandora, Kariobangi North, Korogocho and Baba Ndogo, home to about a million of predominantly low income informal sector workers. (Njoroge, 2007).

Although metals have become increasingly important as a pollutant group, only during the last three decades or so have they been widely acknowledged as potentially dangerous environmental toxins. (Domy, 2001). The growing concern over environmental pollution has let to a generalized usage of the term "heavy metals" and several synonyms (trace metals, heavy elements and toxic metals) which are difficulty to define. (David et al., 1999). Heavy metals leaching from solid waste facilities pose concerns because of the metal ions being distributed to surroundings through surface, subsurface, lateral and/or vertical movement of water. (Eldin et al., 2008).

The environmental problems related to heavy metals have a long history. Heavy metals have toxic properties, leading to adverse effects on human and ecosystem health even in small doses. Accumulation in the food chain may lead to an increased stock in biota, thereby magnifying the human dose. (Ester *et al*, 2000, pp.4).

Although several adverse health effects of heavy metals have been known for a long time, exposure to heavy metals continues, and is even increasing in some parts of the world, in particular in less developed countries, though emissions have declined in most developed countries over the last 100 years. Bull, 2003).

Cadmium occurs naturally in ores together with zinc, lead and copper. Cadmium containing products are rarely re-cycled, but frequently dumped together with household waste, thereby contaminating the environment, especially if the waste is incinerated. (Bull, 2003). Of all the non-essential heavy metal, cadmium is perhaps the metal which has attracted most attention due to its potential toxicity to man. (Bal et al., 1999).

Mercury is primarily exposed to human via food, fish being a major source of methyl mercury exposure and dental amalgam, although certain groups with high fish consumption may attain blood levels associated with a low risk of neurological damage to adults. Lead is neither an essential nor a beneficial element for plants or animals. It is well known however for being poisonous for mammals. There are fears that human body burdens below those at which clinical symptoms of lead toxicity appear may cause mental impairment in young children. (Alloway, 1995).

Population is exposed to lead from air and food in roughly equal proportions. Earlier lead in food stuff originated from pots used for cooking and storage, and lead acetate was previously used to sweeten port wine. During the last century, lead emissions to ambient air have further polluted our environment, over 50% of lead emissions originating from petrol. (Bull, 2003).

In the past, solid waste management primarily included collection, land disposal and incineration of household waste. Industrial waste disposal did not receive much attention. Environmental awareness by the general public increased over time because of various reasons such as advancement in environmental science and technology and interest in pollution related health problems. Attention was also drawn toward the fact that earth's material and energy resources are finite. (Meadows et al., (1972). It became apparent that land filling and incineration have significant environmental impacts and that land filling and incineration are not enough to deal with huge volumes of solid waste generated by communities and industries. (Amalendu, 2004:3).

Integrated Waste Management (I.W.M) is the most important approach for the management of wastes. Rather than incurring the costs and risks of managing waste, it has been recognized, it is better to reduce the generation of waste. Technologies as incineration, chemical detoxification and biological treatment of waste can lead to a major decrease in the toxicity and volume and thus a minimization of the pollution potential of waste when disposed off, e.g. by land filling. (Niir, 2003, P.9, 10).

The challenge of providing adequate hazardous waste management is generally being poorly met. The regulations governing waste disposal are changing rapidly and are enforced in an irregular manner. (Joseph et al., 1990: 4).

MATERIALS AND METHODS

Environmental exposure assessment was done by analyzing of soil samples collected adjacent to the Dandora dumpsite and water samples collected from Nairobi River passing near the Dandora dumping site and its environs. This activity was carried out during the long rainfall period of March to July. Physical environmental assessment was done at the Dandora waste dumping site and at covariate study area prior to the collection of environmental samples to determine locations that were suitable for sampling. Five points for the collection of water and soil samples were selected at a distance of 50m intervals along the Nairobi River and on the lower part of the dumpsite. The reason for selecting this site for study was based on the rapid growth of the informal settlements around Dandora dumpsite and the environmental impact it was to create. The method of selecting 5 soil samples 50m apart away from the dumpsite was to help in determining whether these distances affected the concentration of heavy metals in the soil. Again the five water sampling points were selected based on the early method used for the soil. A desk top study for comparative analysis with the field results was carried out on the previous studies carried on Environmental Pollution and Impact to Public Health; Implication of the Dandora Municipal Dumping Site in Nairobi, Kenya (Njoroge, 2007) and Metal Status of Nairobi River Waters and their Bioaccumulation in Labeo Cylindricus (Budambula, 2005). The two desktop studies were thoroughly carried and the information analyzed together with the field one.

Collection of soil samples

Soil samples were taken at a depth of 30 cm using a soil Auger in five locations at 50m apart in adjacent to the dumping site. A total of five samples were thus obtained from the neighborhood of the dumping site. The samples were then put in a 1 kg polythene papers, put in a container and transported to the University Environmental Engineering laboratory for analysis.

Collection of water samples

Water samples were drawn from five different locations on slow flowing part of Nairobi River at distances of 50m apart bordering the dumpsite. The water samples were dispensed into five one liter plastic bottles and labeled

Sample analysis

To ensure reliable results for the analysis of environmental samples, the quality control and assurance protocols according to respective analyzing laboratories were followed. Appropriate analytical systems calibration was done and quality control materials were analyzed prior to sample analysis. The collected soil and water samples were sent to the Department of Environmental Engineering laboratory at the Jomo Kenyatta University of Agriculture and

Table 1: Cadmium concentration in water from Nairobi River

Element (Cd)	Sample code	Conc (mg/l)	WHO (0.05 mg/l limit)
	WS1	0.50	
	WS2	0.24	
	WS3	0.15	
	WS4	0.8	
	WS5	0.1	

Table 2: Lead concentration in water from Nairobi River

Element (Pb)	Sample code	Conc (mg/l)	WHO (0.015 mg/l limit)
	WS1	1.10	
	WS2	1.40	
	WS3	1.78	
	WS4	0.84	
	WS5	0.5	

Table 3: Mercury concentration in water from Nairobi River

Element (Hg)	Sample code	Conc (mg/l)	WHO (1.5 mg/l limit)
	WS1	2.7	
	WS2	1.66	
	WS3	0.91	
	WS4	2.13	
	WS5	2.0	

Technology for Mercury, Lead and Cadmium heavy metals concentration using USEPA Method, 3050B-Acid digestion of sediments, sludges and soils.

Water sample analysis procedure

The following two reagents were used in the analysis; (i). HCL: H_2O (1:1), (ii). HNO_3: H_2O (1:1). The water was filtered; 100ml put into 250ml beakers and heated. 10ml of reagent 1 and 2ml of reagent 2 were added, heated on a hot plate until volume was reduced to 10ml, distilled water was topped up to 100ml and filtered and samples made ready for analysis using the Atomic Absorption Spectrophotometry.

RESULTS AND DISCUSSIONS

Soil sample analysis procedure

The reagents used for this analysis were (i). 5% Hydrochloric acid (ii). Acid mixture used: (Nitric acid: Sulphuric acid: perchloric acid= 6:3:1), 20% Potassium Iodide solution. The soil samples were dried in the oven at 105° C for 1-3 hours and grinded into powder, weighted a bout 1g of each into a 100ml beaker, added 5ml of the acid mixture, shaken well to allow it to stand for 5 minutes, digested on a hot plate starting at 70° through to 120° until volume reduced to about 1ml and production of floating suspended white fumes of $S0_3$ clearly observed**,** allowed to cool at room temperature and added 20ml of the 5% HCI acid solution, heated on hot plate at about 75° C for 15 minutes then allowed to cool, filtered through whatman number 42 into a 100 ml volumetric flask and topped up with 5% HCI. After this had been done, samples were taken for analysis by AAS for mercury, lead and cadmium heavy metals.

To ensure reliable results for the analysis of the environmental samples (soil and water), the quality control and assurance protocols according to respective analyzing laboratories was adhered to**.** Elemental concentrations for heavy metals obtained for individual soil and water samples from land and Nairobi River at Dandora dumpsite are indicated in tables 1 to 6.

Field Study

Heavy metal concentration from Nairobi River (table 1-3 and figure 1)

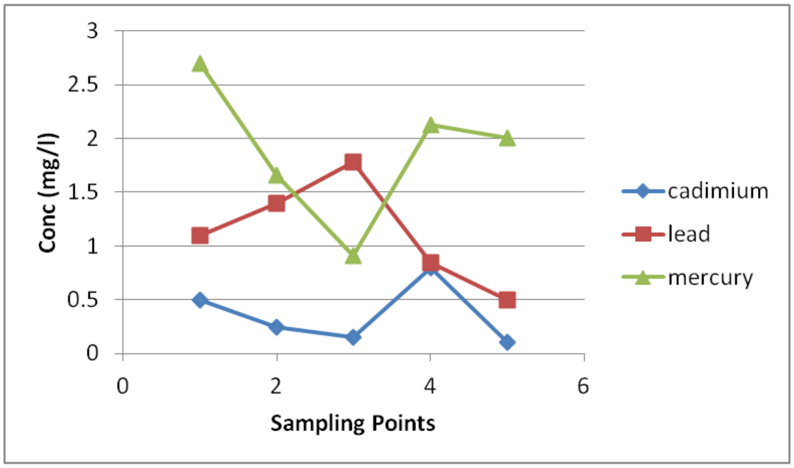

Figure 1: Graph showing cadmium, lead and mercury heavy metal concentration in water.

Table 4: Cadmium concentration from soil near Dandora dumpsite

Element (Cd)	Sample code	Conc (mg/kg)	WHO (0.05 mg/kg limit)
	SS1	44	
	SS2	35.8	
	SS3	27.2	
	SS4	23	
	SS5	19.4	

Table 5: Lead concentration from soil near Dandora dumpsite

Element (Pb)	Sample code	Conc (mg/kg)	WHO (100 mg/kg limit)
	SS1	240	
	SS2	180.4	
	SS3	171.0	
	SS4	114.6	
	SS5	109.8	

Table 6: Mercury concentration from soil near Dandora dumpsite

Element (Hg)	Sample code	Conc (mg/kg)	WHO (2 mg/kg limit)
	SS1	24	
	SS2	18.6	
	SS3	15	
	SS4	12	
	SS5	5.5	

Heavy metal concentration from soil near Dandora dumpsite

Desk top study results for Environmental Pollution and Impact to Public Health; Implication of the Dandora Municipal Dumping Site in Nairobi, Kenya

The total elemental concentrations for trace elements and heavy metals obtained during the month of July from individual soil samples from Korogocho/Dandora are indicated in table 8.

Desk top results for Metal Status of Nairobi River Waters and their Bioaccumulation in Labeo Cylindricus

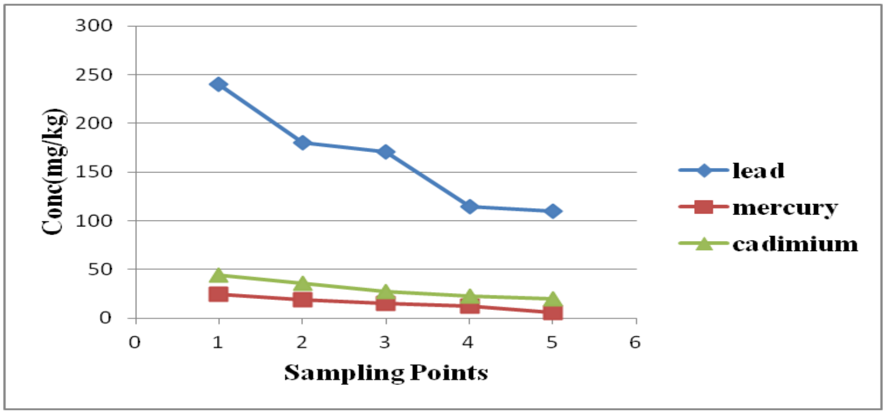

Figure 2: Graph showing cadmium, lead and mercury heavy metal concentration in soil.

Table 7: Elemental concentration in soil samples from specific sampling sites of Dandora and Korogocho

Elements	Elemental concentration in Dandora soil samples in ppm					WHO/KBS Reference values(mg/kg)
	E1	E2	E3	E4	E5	
Hg	BDL	BDL	18.6	BDL	BDL	1000
Pb	185	66	453	560	68	50
Cd	Surface-52.9			Subsurface – 26.5		5.0

Source: Njoroge, 2007

Table 8: Comparison of the concentration of the desk top with the field study results of concentrations of heavy metals (mg/kg) in Dandora/Korogocho and Waithaka soil samples.

Element	Desk top results		Heavy metal concentrations in the study soil samples	WHO/KBS Reference values (mg/kg)
	Dandora/Korogocho	Waithaka	Dandora	
Hg	18.6	BDL	5.5<24	1000
Pb	50-590	35	109.8<240	50
Cd	27-53	BDL		5.0

Source: Njoroge, 2007

Table 9: Results for total concentration in soil samples obtained at Waithaka which is 20 km upstream.

Elements	ECI	EC2	Mean standard deviation	WHO/KBS Reference values (mg/kg)
Hg	BDL	BDL	BDL	1000
Pb	35	34	34.5± 0.7	50
Cd	BDL	BDL	BDL	5.0

Source: Njoroge, 2007

Table 10: Elemental concentration in the compost sample from the Dandora waste dumping site

Elements	Elemental concentrations in mg/kg	WHO/KBS Reference values (mg/kg)
Hg	46.6	1000
Pb	13500	50
Cd	1058	5.0

Source: Njoroge, 2007

Table 11: Concentrations lead levels (mg/l) of metals in water at six sampling sites along the Nairobi River

Sampling site	Lead
Kikuyu	BDL
Kawangware	BDL
Chiromo	BDL
Eastleigh	BDL
Njiru	200
Fourteen Falls	200

Source: Budambula, 2005

Table 12: Concentration Cadmium levels (mg/l) of metals in water at six sampling sites along the Nairobi River

Sampling site	Cadmium
Kikuyu	BDL
Kawangware	25
Chiromo	25
Eastleigh	25
Njiru	25
Fourteen Falls	25

Source: Budambula, 2005

Table 13: Concentration Mercury levels (mg/l) of metals in water at six sampling sites along the Nairobi River

Sampling site	Mercury
Kikuyu	BDL
Kawangware	BDL
Chiromo	BDL
Eastleigh	BDL
Njiru	BDL
Fourteen Falls	BDL

Source: Budambula, 2005

DISCUSSIONS

Field discussion

Soil and water samples from Dandora dumpsite were analyzed to determine the three selected heavy metals concentrations. A comparative analysis of these results were further carried out together with those of the two desk top studies; Environmental Pollution and Impact to Public Health; Implication of the Dandora Municipal Dumping Site in Nairobi, Kenya (Njoroge,2007) and Metal Status of Nairobi River Waters and their Bioaccumulation in Labeo Cylindricus (Budambula,2005). The analysis of the samples served to determine the status of the environment around the dumping site and thus an indicator of environmental impact of waste disposal at the site.

From the field study results of water analyzed for heavy metal concentrations from Nairobi River, cadmium was more concentrated at point WS4, lead at point WS3 and mercury at point WS1. It was also noted that cadmium, lead and mercury concentrations were lowest at points WS5 andWS3 as shown in Tables 6 and 7 above. This scenario could be attributed to leachate that was noticed coming from different sections of the dumpsite into the river. The type of waste and where deposited most, river flow speed variance at different points due to obstructions caused by stones, logs and vegetation were found to also be contributing factors.

Tables 6 and 7 above show the three heavy metal concentration graph.

The results obtained from the soil sample analysis, cadmium, lead and mercury were highest in concentration near the dumpsite and decreased significantly away from it. There was remarkable reduction of heavy metal concentrations in both water and the soil samples taken for analysis as compared to the results obtained from "Implications of the Dandora Municipal Dumping Site in Nairobi", Kenya (Njoroge, 2007). This reduction was noted to be as a result of the current government of Kenya clean up campaign of the Nairobi River and the Nairobi City Municipal waste management program fronted by the ministry of Environment.

The WHO heavy metal concentration limits which the Kenya government has adopted though not full practiced were found to be very high in both water and soil samples analyzed. The only noted lower concentration was in sample WS3 which was 0.91 mg/kg as compared to WHO limit of 1.5 mg/kg. This was attributed to the point of sample collection being far away from heavy mercury concentration leachate as compared to others.

Desk Top Discussions

Environmental Pollution and Impact to Public Health; Implication of the Dandora Municipal Dumping Site in Nairobi, Kenya (Njoroge, 2007)

Table. 8 shows soil samples taken from Dandora/ Korogocho sites during the month of April, mercury concentration was detected at point E3 (18.6 mg/kg which was below WHO/KBS limit, lead was high in all the two sites and highest at E4 as compared to the WHO/KBS limits of 50. mg/kg Cadmium both at surface (52.9 mg/kg) and subsurface (26.5 mg/kg were again above 0.05 mg/kg WHO/KBS limits. Tables 9 and 10 show low heavy metal concentrations in soil samples collected at Waithaka. The reason for this was attributed to fewer pollutants in that area. Results in table 11 obtained from the compost samples inside the Dandora dumpsite show extremely very high levels of heavy metal concentration of mercury, lead and cadmium as compared to other areas. This was attributed to wastes with heavy content these metals being dumped at the same place.

Metal Status of Nairobi River Waters and their Bioaccumulation in Labeo Cylindricus (Budambula, 2005)

The results from tables 12-14 show lead concentration in Nairobi River being higher at Njiru (200 mg/l) and Fourteen Falls (200 mg/l) as compared to WHO/KBS limits of 50ppm. Cadmium concentrations from Kawangware, Chiromo Eastleigh, Njiru and Fourteen Falls at 25 mg/l were very high when compared to the WHO/KBS limits of 0.05 mg/l. All the three heavy metal concentration at Kikuyu were below the detectable levels.

Kikuyu point is where the Nairobi River originates from and has therefore fewer pollutants when compared to Kawangware, Chiromo, Eastleigh, Njiru and Fourteen Falls. These areas are situated on the route of heavy pollutants. Table 13, show mercury concentrations from all the six points were found to be below detectable levels. The low levels were attributed to less mercury containing pollutant passing through the area. From the overall results obtained both from field and desk top studies, it was noted that heavy metal concentration was found to be more near the polluting routes of Kawangware, Chiromo, Eastleigh, Dandora, Njiru and Fourteen Falls, as compared to Waithaka and particularly Kikuyu where there were fewer pollutants.

CONCLUSIONS

The results obtained in the two studies both field and desk top are evident that waste dumping at Dandora waste dumpsite is a potential source of environmental pollution and a risk to the health of people living within and surrounding the dumpsite. From the two desk top studies, it is evident that there was less pollution from the Kikuyu site which is the source of the Nairobi River, but as the river passes through the informal settlement route, more pollution was more pronounced. Soil samples taken within the desk top study areas again showed more heavy metal concentration near the dumpsite than away from it. The results call for immediate action to prevent continued public exposure to environmental pollution, need to correlated observation from other areas that are at specific distances away from the dumpsite and other non polluted environments. More environmental samples including air samples should be analyzed to evaluate the environment. More sensitive markers of toxicity should be used to ascertain long term effects of exposure. Experience in the process of conducting this study indicates a great need to link environmental pollution and human health. Dandora dumpsite and other informal settlement mentioned in the desk study are a threat to the environment as litter is blown out of the site and poisonous leachates continue to contaminate the Nairobi River and the soil. The Dandora dumpsite should be improved upon and attention given so that they do not become environmental hazards.

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