GREENER JOURNALS

Greener Journal of Medical Sciences

ISSN: 2276-7797

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By

Nkonge Njagi Ananias
Prof. Magambo K Japhet
Prof. Oloo Mayabi
Dr. Kithinji Jacob
Ndwiga Taratisio

Research Article

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[1*]Nkonge Njagi Ananias, [2]Prof. Magambo K Japhet, [3]Prof. Oloo Mayabi, [4]Dr. Kithinji Jacob, [5]Ndwiga Taratisio

[1*,5]Department of Environmental Health, School of Public Health, Moi University Eldoret Kenya
[2,3]Jomo-kenyatta University of Agriculture and Technology Nairobi Kenya
[4]University of Nairobi Nairobi Kenya

*Corresponding Author's Email: annkonge@gmail.com, Mobile. +254722609366

ABSTRACT

The bottom-ash left after incinerating health-care waste may contain heavy metals which may leach and pollute the environment if not properly disposed of. Bottom ash samples were taken from Moi Teaching and Referral Hospital incinerator, and disposal pit ashes from an excavation of an adjacent abandoned pit. Concentrations of total chromium, cadmium, lead, silver and mercury were analyzed with Atomic absorption spectrophotometer.
Concentration of the heavy metals in the bottom ash and soils were found to exceed the maximum levels specified by National Environmental Management and Co-ordination Act and European Union Standards.
There was evidence of heavy metals leaching from pit-ashes and permeating along the ground profile. These were traced at intervals of 250mm along the 2m excavated profile. The disposal pit was not lined making it possible for the leaching heavy metals to permeate and pollute the groundnut whose phreatic surface was at 2m depth.

Keywords: Bottom-ash; heavy metals; leaching; pollution risk.

INTRODUCTION

Medical waste forms 15% of the hospital waste which is considered as hazardous and may be toxic or radioactive (WHO, 1994). Managing it calls for a heavy responsibility, as it is dirty, foul, difficult, expensive and a technically complicated task. If not done properly can cause significant inconvenience and become a health risk (Naioova, 2000; Sheshinski et al., 2002; WHO, 2004). Risk is a probability that a particular adverse event occurs during a stated period of time (Ford et al., 2004).

The management practice may pose as a risk, and may very likely pollute the environment through emitted smoke and improperly disposed of bottom ash of incinerators. Incineration of medical waste as a treatment option is viewed as dangerous (Ridlington et al., 2004). The practice is worsened by operation of incinerators by untrained or improperly trained operators. (Batterman, 2004).

While incinerating medical waste, waste that may contain heavy metals should be segregated and excluded for separate treatment so as to ensure that the environment is not polluted by their emissions and residues posing a risk to public health. Healthcare waste containing mercury if incinerated without care would release mercury vapor in the environment which if inhaled by humans may be toxic, fatal or lead to life threatening injuries to lungs and neurological systems (Howard, 2002; UNEP, 2009).The ashes that remain at the bottom of the incinerator after burn contain heavy metals. Medical waste has more heavy metals than municipal solid waste (Takeuchi et al., 2005; Sabiha-Javied and Tufai, 2008; Zhaho et al., 2010). Waste from dental clinics broken thermometers mistaken as sharps contain mercury (EPA, 2011;Vieira et al.,2009;Mazrui, 2010; Calhoum, 2003) which if incinerated leave mercury residue while the rest is released in the environment posing a great risk to the public.

Cadmium, a heavy metal also common in red bags used to store infectious waste (Hill, 1997; Lee and Huffman, 2002) if incinerated and taken by humans, bio-accumulates in kidneys with the content increasing with age. It causes human kidney damage and emphysema.

Chromium, also a product of incinerated plastics leather treated products in industry, if incinerated and gaseous emissions inhaled or consumed orally (chromium vi) can cause cancer (WHO, 1996; Howard, 2002).

Lead commonly found in paints and plastic liners of health-care waste bins if released in the environment acts as a cumulative poison, and has adverse effect on nervous system of developing fetuses, and could cause convulsion, comma, renal failure and death (Hill, 1997; Howard, 2002).

Silver, a metal associated with photographic materials used in X-Ray films and also present in dental amalgam if released during incineration and excessively ingested, would cause skin, eyes and mucous membrane discoloration (Hill, 1997). In its ionic form, it is more toxic to aquatic organisms than any other metal except mercury.

The management practice may pose as a risk, and may very likely pollute the environment through emitted smoke and improperly disposed of bottom ash of incinerators. Incineration of medical waste as a treatment option is viewed as dangerous (Ridlington et al., 2004). The practice is worsened by operation of incinerators by untrained or improperly trained operators. (Batterman, 2004).

METHODOLOGY

A daily batch of bottom ash from the hospital incinerator, at MTRH was sampled and weighed in triplicate packs of 30gs each.

This was done in the hospitals for 30 consecutive days. The sampling was done in November, 2008.

The research assistant who is also a trained health technician, practicing in the hospital was instructed on how to take bottom ash samples from an incinerator through quartering method to arrive at quantities of ashes sufficient to make 30g sample packs in triplicate that excluded stone pebbles. The chief investigator worked with him for the first ten days to ensure that he had no problems.

An excavation from an abandoned ash pit where the incinerator ashes had been buried was done and triplicate samples of the exhumed ashes in 30gms taken through quartering method. Further excavation below the pit invert to a depth of 1000 mm was done and at intervals of 250mm; triplicate samples of soil weighing 30 gms were taken.

The samples were later ground, sieved and weighed in 1 gm quantities, digested and the extract analysed for heavy metals using standard method (Endham and Barnes, 2000) and use of Atomic Absorption Spectrophotometer (AAS).

RESULTS AND DISCUSSION

Incinerator bottom-ash samples

The following were the mean daily concentrations of the heavy metals under study as isolated from the incinerators bottom ash.

Table 1.0: Heavy Metals in Bottom Ash of Hospital Incinerator (MTRH)

Item (30 days samples)	Chromium mg/L (daily mean conc.)	Cadmium mg/L (daily mean conc.)	Lead mg/L (daily mean conc.)	Silver mg/L (daily mean conc.)	Mercury mg/L (daily mean conc.)
Mean	3.87	0.25	4.34	1.36	0.04
SD	2.20	0.18	2.70	0.60	0.05
VARIANCE	4.83	0.031	7.29	0.35	0.002
Mean mg/kg of ashes	3870	250	4340	1360	40

The mean operation readings for the incinerator at MTRH were 186^{0}C minimum and 938^{0}C maximum.

Table 2.0: Maximum Permissible Levels (NEMA/WSRB)

	Enforcing Body	Heavy Metal	Max. Conc. mg/L
1	NEMA/WSRB	Lead	0.01
2	- do -	Lead and it compounds	0.1
3	- do -	Chromium (vi)	0.05
4	- do -	Chromium (total)	2.0
5	- do -	Cadmium	0.01
6	- do -	Cadmium and its compounds	0.1
7		Total mercury	0.005
8	EPA (US)	Silver	0.14

-NEMA-National Environmental Management Authority. (Kenya)
-WSRP-Water Services Regulatory Board. (Kenya)
-Environmental Protection Authority of United States.

From the analysis, the mean levels of the five pollutants (heavy metals) recovered from the bottom ash at MTRH incinerator are higher than the standards specified by NEMA/WSRB and US, EPA for the respective metals for disposal into receiving water bodies or the environment.

All the metals, chromium (total), cadmium, lead and mercury have a high statistical significance and are significantly different from standard(NEMA/WSRB, Guidelines, 2006) level as appears in Table 2.0 above, and are significantly different, p = 0.000 (df=29). Similarly, silver is highly significantly different from a standard EPA (US), p = 0.000 (df=29) (same table).

This was bottom ash with mean concentrations of heavy metals, total chromium, cadmium, lead, silver and mercury of 3870, 250, 4340, 1360 and 40 mg/kg, respectively, which if not properly disposed of is likely to leach from the ashes and pollute the environment.

Incinerating healthcare waste bearing mercury risks public health as it readily sublimes, appearing as vapor in the environment and can be inhaled by humans. The positions of the two incinerators under study in the two institutions by virtue of their situation make render the heavy metals they discharge a public health risk. This is an obvious threat because when mercury at unacceptable concentration was traceable in bottom ash of incinerator, it implies that much of it had undergone sublimation and was discharged as mercury vapor risking public health of the people in the two institutions. The healthcare waste likely to emit mercury during incineration, a heavy metal isolated from the bottom ash, include dental amalgam from dental clinics which has 50% mercury, (Calhoum,2003) thermometers, blood pressure cuffs, laboratory chemicals, certain electrical switches, paints, fluorescent lumps and bulbs (GAIA, 2009). Cadmium bearing waste that if incinerated would contribute this heavy metal traced in the bottom ash would be red liner plastic bags used for refuse bins (Hill, 1997). Lead, which was also isolate in high quantities in the incinerators of the two institutions, would originate from incinerated red liner bags used for storage of infectious waste, paints and batteries (Hill, 1997; Howard, 2002). The source for silver in the bottom ash of the incinerators must have originated from photographic material used for X-Ray films, although the waste category was not among the four studied.

Ash-pit Profile Samples

The ashes and soil samples taken from a closed and abandoned ash-pit at MTRH disposal ground were intended to assist in the investigation of heavy metals presence and possible concentrations in the disposed of ashes, evidence of leaching and permeating downwards along the ground profile, and possibly to the ground water hence posing as risk to public health.

Heavy metal concentration along pit profile

The coefficient of conductivity (k) for the disturbed soil samples taken below the ash-pit invert was computed based on Jackson and Dhir (1988) formula and was found to be 4.896 x 10 - 4 mm/sec.

The heavy metals concentrations in the ash-pit, chromium, cadmium, and lead at 5.20, 0.13, and 3.28 mg/L respectively are higher than the maximum levels set by National Environmental Co-ordination Agency as presented in Table 2.0.

The concentration of mercury at 0.003 mg/l in the ash-pit buried ashes is below the maximum level of 0.005 mg/L stipulated for disposal in the environment by National Environmental Management and Co-ordination Act without appropriate care.

The concentration of silver at 0.17mg/L in the ash-pit ashes is above the maximum permitted level permitted by US, Environmental Protection Agency for disposal in the environment.

The proportional concentrations of heavy metals in relation to ashes that contained them at the disposal ash-pit of MTRH, was 5200; 130; 3280 and 170 mg/kg of total chromium, cadmium, lead, and silver, respectively exceed the maximum limit regulated by NEMA for ordinary disposal in the environment without taking appropriate measures against environmental pollution should leach pollute drinking water supplies.

At 1000mm depth below the ash-pit invert, the concentration of lead found at that depth, which was saturated with groundwater was 2.80 mg/L. This exceeded the maximum permitted level by National Environmental Management and Co-ordination Act.

The cadmium at par with the National Environmental Management and Co-ordination Act (NEM&CA) permitted concentration of 0.01 mg/L.

No mercury was traced at this level.

Chromium concentration in the soil at 1000 mm level along the pit profile was 1.28 mg/L and was below the maximum permitted level in the environment by National Environmental Management and Co-ordination Act.

Silver concentration of 0.17 mg/L is above the maximum permitted level permitted for disposal in the environment by the US, Environmental Protection Agency.

Evidence of heavy metals permeating downwards along the ground profile is presented on Tables 3.0, 4.0 and Fig, 1.0.

Table 3.0 below, shows the concentrations of the four heavy metals recovered as they permeate along the pit profile.

Table: 3.0 MTRH-Ash-Pit-Profile- Blood Bank Site Eldoret

Ash-Pit Levels	Chromium mg/L (mean conc.)	Cadmium mg/L (mean conc.)	Lead mg/L (mean conc.)	Silver mg/L (mean conc.)	Mercury mg/L (mean conc.)
Ash-pit	5.20	0.13	3.28	0.17	0.003
250mm	3.29	0.04	3.00	0.14	0.003
500mm	2.32	0.00	2.87	0.13	0.000
750mm	2.26	0.01	2.80	0.17	0.010
1000mm	1.28	0.01	2.80	0.17	0.000

Table 4.0: Heavy Metals Proportion mg/kg of Ashes and Soil.

Ash-Pit Levels	Chromium (mean conc.) mg/kg of-	Cadmium (mean conc.) mg/kg of-	Lead (mean conc.) mg/kg of-	Silver (mean conc.) mg/kg of-	Mercury mg/l (mean conc.) Mg/kg of-
Ash-pit (ashes)	5200	130	3280	170	3
250mm (soil)	3290	40	3000	140	3
500mm (soil)	2320	0.0	2870	130	0.0
750mm (soil)	2260	10	2800	170	10
1000mm (soil)	1280	10	2800	170	0.0

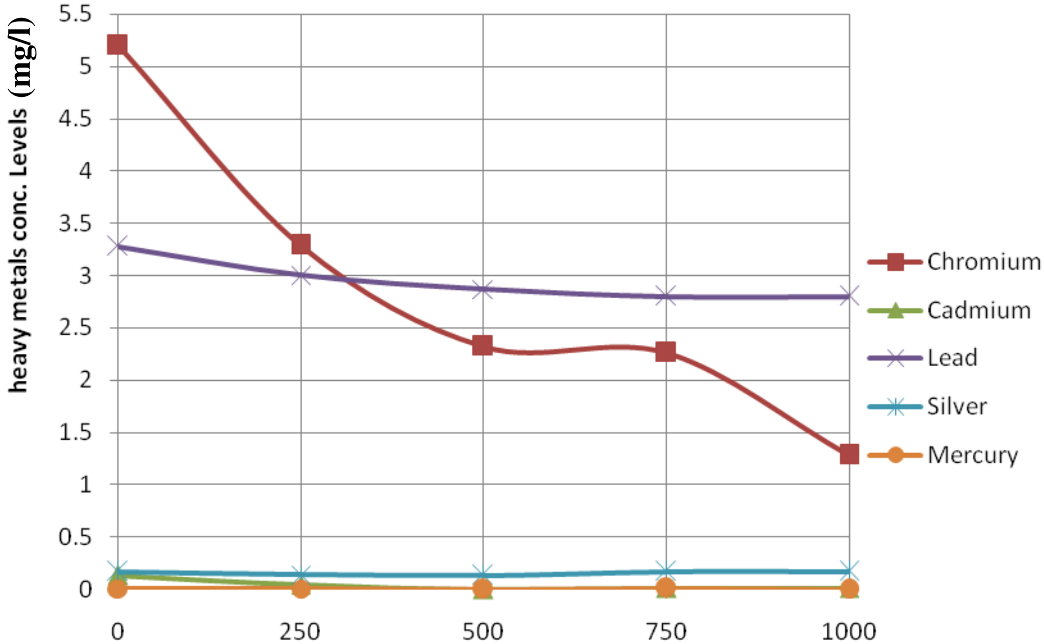

Fig.1-Ash Pit invert profile (mm)

At ash-pit topmost depth of 1m where the incinerator ashes were recovered for analysis, the proportional concentrations of heavy metals to ashes, mg/kg were 5200; 130; 3280; 170 and 3, for total chromium, cadmium, lead, silver, and mercury respectively. All the concentrations in the ashes, except for mercury, were higher than the levels specified by the two standards for disposal in the environment without adequate care against pollution, and for this case groundwater which is likely to be consumed by humans downstream.

At 1m depth below the ash-pit invert, a depth where during this pit excavation, water saturated soil was reached; the proportional concentrations of heavy metals to the soil, lead and silver were higher than the standards. Concentration of cadmium was just at maximum limit. The remaining two, total chromium and mercury fell below the maximum limit. The concentrations of the said heavy metals to soil at that level was 1280; 10; 2800; 170 and 0.0 mg/kg of total chromium, cadmium, lead, silver and mercury, respectively.

The permeability test on the soil below the ash-pit profile was a clay of medium plasticity; a well graded soil of medium consistency with a coefficient of conductivity, of k=4.896x10-4mm/sec. (0.4896μm/sec). This level of permeability based on Jackson and Dhir (1988) categorizes it in a permeability range of k =0.1-10 μm $s^{-1.}$

It falls within low permeability category but capable of allowing the heavy metal pollutants to permeate into the ground hence the soil type that would require lining of the pit before disposal of incinerator bottom ash.

CONCLUSION

The incinerator under study had the concentrations of heavy metals; total chromium, cadmium, lead, silver and mercury in the bottom ashes were 3870, 250, 4340, 1360 and 40 mg/kg respectively that exceeded the maximum levels specified by National Environmental Management Agency and United State Environmental Protection Agency. Disposal of the incinerators bottom ash at MTRH was done in unlined pits without providing care against environmental pollution. This risked ground water pollution with high concentrations of heavy metals traced in the bottom ash of the hospitals incinerator. The concentration of total chromium, cadmium, lead silver and mercury in the excavated pit ash in the abandoned pit ash were 5200, 130, 3280 170 and 3 mg/kg, which were higher than the maximum allowable limits for ordinary disposal in the environment. The same pollutants were found to be leaching from the ashes and permeating along the excavated ground profile with a risk of polluting ground water.

ACKNOWLEDGEMENT

The authors wish to thank the management of Moi University, Eldoret and Moi Teaching and Referral Hospital for financial support to complete this study. The approval of the study by National Science and Technology and Institutional Ethics Committee of MTRH is also appreciated.

Further appreciation is recognized by the research assistants of MTRH who with their familiarity made data collection possible.

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