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# COMPARATIVE STUDY OF HEAVY METALS IN BOTTOM ASH FROM INCINERATORS AND OPEN PIT FROM HEALTHCARE FACILITIES IN GHANA

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**Abstract:** Treatment of healthcare waste either by incinerating or open burning in a pit produces bottom ashes which contains heavy metals and other chemicals which are toxic, persistent and accumulate in the food chain resulting in adverse health effects in human and the environment. The study investigated the level of heavy metals in the ashes of thermally treated medical waste from four health care facilities in Ghana. Two batch of the ash samples were collected from two hospital incinerators and the other two from medical waste burnt in an open-pit. The samples were collected on different days but within the same month, stored and transported to Water Research Institute laboratory for heavy metals analysis. The concentrations of Pb, Cd, Cr and Hg were assessed using Atomic Absorption Spectrophotometry (AAS). The results proved that the concentrations of heavy metals were higher for the waste treated in the incinerator than those burnt in the open pit. The average concentration of the metals in the ashes were in the following decreasing order Pb>Cr>Hg>Cd. The mean concentration of Pb from the incinerated bottom ash was 147.5mg/kg and Cd was 2.5mg/kg whilst the open pit was (69.67mg/kg) and (1.34mg/kg) respectively. All the metals investigated exceeded the Dutch and Danish limit values for maximum permissible levels of heavy metals in good soil quality and therefore classified as harmful and toxic and therefore proper attention should be given to the ash disposal at the landfill sites.
**Keywords:** Bottom ash; Ghana; Heavy metals; Healthcare waste; Incineration.
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## INTRODUCTION

Healthcare waste management is a critical issue of global concern. This is rightly so because of the potential health risk associated with handling, storage, treatment and disposal of such waste. It has been established that about 10 to 25 per cent of the waste from healthcare activities are infectious and hazardous (Run-dong *et al.,* 2006; WHO, 2013). The rest are said to have characteristics similar to domestic waste (Altin *et al.,* 2002, WHO, 2013). It is therefore important to effectively treat the small component of the healthcare waste that could pose threat to public and environmental health. There are array of treatment technologies available for healthcare waste treatment but their selection needs to be done carefully (Emmanuel, 2007). One of such technology is the incineration of waste using different types of incinerators. Incineration is the process of using high dry heat system to combust waste of different kinds in an incinerator through and oxidative process. This treatment technology has been widely used for treating healthcare waste because of its ability to reduce the volume and mass of waste by about 80-90%, hygienised the waste and make it unrecognisable (Batterman, 2004; Salkin *et al*., 2000: UNEP, 2012). According to Thompson and Anthony (2008), incineration of waste produces a large amount of ash (30%) of the weight of the original waste. Small scale incinerator treatment technology has its own setbacks but has been referred to as transitional treatment technology appropriate for developing countries (Batterman, 2004). The technology is widely used in developing countries including Ghana despite being implicated for the emission of toxic gases such as dioxins and furans (Knox, 2005; Petrlík and Ryder, 2005). Racho, (2002) indicated that incineration can concentrate inorganic toxic materials such as of heavy metals in the waste in the ash residues (bottom ash and fly ash). Bottom ash makes up about 90 percent of the total ash produced during waste incineration and has been shown to contain significant concentrations of heavy metals and other chemical pollutants (Greenpeace, 1991). Heavy metals have been found in both bottom and fly ashes produced by incinerators used for treating municipal waste. Shams *et al.,* (2012) studied heavy metals in bottom ash from municipal incinerators and reported that the concentration of Cu, Cr and Pb all exceeded the tolerable level except the concentration of Cd. Racho, (2002) among other things assessed the quantities of heavy metals in the residual bottom ash from incineration of medical waste in Ratchasima-Thonburi Hospital. She reported that average concentrations of lead, silver, iron, and zinc to be 0.08, 0.07, 0.21 and 0.26 mg/L, respectively which were below the limits set by the Thai Ministry of Industry. Analysis of bottom ash samples taken from Moi Teaching and Referral Hospital incinerator showed higher concentration of total chromium, cadmium, lead, silver and mercury which exceeded the maximum levels specified by National Environmental Management and Co-ordination Act in Kenya and European Union Standards (Nkonge *et al.,* 2012). Picken, (2007) indicated that the use of De Montfort incinerator for healthcare waste treatment is better than open burning. Study to examine the heavy metal concentration of the incinerated ash from the De Montfort incinerator in comparison with the openly burnt medical waste in a pit is limited in literature. The study therefore aimed at examining the level of selected heavy metals [Lead (Pb), Cadmium (Cd), Mercury (Hg) and Chromium (Cr)] in the bottom ash of De Montfort incinerator and ash from hand dug pit use for burning hospital waste. It further examined the possible environmental effects of the metals with concentrations above the standard limits in the environment.

## EXPERIMENTAL

### *Sample collection and treatment*

The study was done in November, 2013 and focused on three (3) hospitals and a community clinic: regional, municipal, psychiatric hospitals and a community clinic. A total of eight (8) samples were picked from these hospitals and the clinic, i.e. in duplicates on different days for the different hospitals in the same month. These were cleaned of any unburnt plastics and sharps and the fine ash were placed in tight plastic containers, well labelled and transported to the Council for Scientific and Industrial Research–Water Research Institute, Accra (CSIR-WRI) for laboratory analysis.

### *Heavy metal analysis*

One gram of the dried sample was weighed and transferred into an acid washed, round bottom flask containing 10 $cm^3$ concentrated nitric acid. The mixture was slowly evaporated over a period of 1 h on a hot plate. Each of the solid residues obtained was digested with a 3:1 concentrated $HNO_3$ and $HClO_4$ mixture for 10 minutes at room temperature before heating on a hot plate. The digested mixture was placed on a hot plate and heated intermittently to ensure a steady temperature of 150°C for about 5 hours until the fumes of $HClO_4$ were completely evaporated (Jacob *et al*., 2009). The mixture was allowed to cool to room temperature and then filtered using Whatman No.1 filter paper into a 50 $cm^3$ volumetric flask and made up to the standard mark with deionized water after rinsing the reacting vessels, to recover any residual metal. The filtrate was then stored in pre-cleaned polyethylene storage bottles ready for analysis. Heavy metal concentrations were determined using an Atomic Absorption Spectrophotometer (AAS). The instrument settings and operational conditions were in accordance with the manufacturer's specifications. The instrument was calibrated with analytical grade standard metal solutions (1 mg/dm$^3$) in replicates. T-test for paired samples with equal variance was used to test for statistical difference between the heavy metals in the ashes sampled from the open pit and the De Montfort incinerators. The concentrations of the metals were compared to Dutch and Danish limit values for maximum permissible levels of heavy metals in good soil quality since the Environmental Protection Agency of Ghana permissible levels were not available.

## RESULTS AND DISCUSSION

From the results (Table 1), the concentration of Pb from the four hospitals ranged from 63.6-166 mg/kg with an average of 108.59 mg/kg while Cr concentrations ranged between 19- 43.2 mg/kg with a mean value of 33.1mg/kg. Cadmium concentrations ranged from 0- 3.33 mg/kg having an average of 3.33 mg/kg. Hg concentrations obtained an average of 2.5 mg/kg while varying from 0- 3.65 mg/kg. The results indicate that Pb had the highest concentrations for all ash samples from the four hospitals whilst Hg recorded the least with a mean value of 166 mg/kg and 2.5 mg/kg respectively. The ashes from the De Montfort incinerator in the regional and municipal hospitals had the highest concentration of Pb as compared to the psychiatric and the clinic that used open burning in hand dug pit for the thermal treatment. There was statistical difference between the concentration of lead (Pb) detected in the incinerated ash and that of the open-pit ($t = 10.29$, $p < 0.05$).

**Table 1. Level of Heavy metals in Bottom ashes taken from Healthcare facilities (mg/kg)**

| Sample ID | Pb | Cr | Cd | Hg |
|---|---|---|---|---|
| **Sample A1** | 166 | 43.2 | 3.33 | ND |
| **Sample A2** | 142 | 40.3 | 3.18 | ND |
| **Sample B1** | 148 | 30 | 0.48 | 3.07 |
| **Sample B2** | 134 | 40 | 3 | 3.65 |
| **Sample C1** | 79 | 40 | ND | 1.7 |
| **Sample C2** | 69 | 28 | ND | 1.58 |
| **Sample D1** | 67.1 | 19 | 1.29 | ND |
| **Sample D2** | 63.6 | 24.3 | 1.38 | ND |
| **mean** | **108.58** | **33.1** | **2.11** | **2.5** |
| **Max** | **166** | **43.2** | **3.33** | **3.65** |
| **Min** | **63.6** | **19** | **0** | **0** |

**NB:** Sample A1, A2, B1 and B2 are from incinerator, C1, C2, D1 and D2 are from open-pit

Chromium (Cr) concentrations of the ash from the incinerated medical waste was higher than the open-pit counterpart but was not statistically significant ($t = 1.99$, $p = 0.09$). Cadmium (Cd) concentrations in the ashes from the two methods of thermal treatment (incinerator and open-pit) were not significantly different ($t = 2.35$, $p = 0.06$) even though the values for the incinerated ones were higher than the open-pit sources observably. Mercury was not detected in the incinerator ash from the municipal hospital and the community clinic but was found in the regional and psychiatric hospitals ashes.

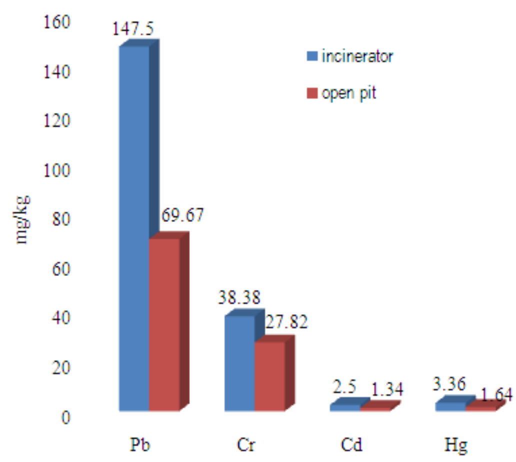


**Figure 1. Concentration of heavy metals from incinerator and open pit**

With respect to the four hospitals, it was observed that the municipal hospital which used incinerator recorded the highest level of the heavy metals with the exception of Hg which was not detected. The Psychiatric hospital obtained the least level of heavy metals concentrations from the four hospitals investigated. It was also clear that the level of heavy metals found in the ashes of the De Montfort incinerator were higher than those from the open-pit. The heavy metal concentrations from the two hospitals *i.e.* municipal and regional hospitals showed that Pb concentrations were higher with mean values of 154 mg/kg and 141 mg/kg from Municipal Hospital and Regional hospital respectively. The high concentrations of Pb in the waste may be due to the contribution from plastics and tubes incinerated in the De Montfort incinerator. According to European Commission (2002) Pb in ashes may come from plastics, lead crystal glass inclusive cathode ray tubes, ceramics, solders, pieces of lead flashing and many other minor products in the waste incinerated. Hickman, (1987) indicated that Pb and Cd are the two most-often found metals in medical waste which mostly comes from plastics. The studied hospitals mostly incinerated sharps which consisted of needles and plastic syringes and therefore it was not surprising that the Pb content was high. This might have accounted for high concentration of Pb in the incinerator than the open pit. Even though sharps are also burnt in open pit practices, they were normally mixed with other combustible waste which probably contributed to the level of Pb in the ash residue. Mercury obtained the lowest value of 0 mg/kg and 3.36 mg/kg from regional hospital and municipal respectively because mercury readily sublimes, appearing as vapour in the environment and poses higher risk to public and environmental health especially neighbouring communities when inhaled. Volatile metals such as mercury may vaporize in the primary combustion chamber and leave the bottom ash when waste is incinerated (Lee *et al.,* 2002)**.** Mercury is found mainly in thermometers, manometers, dental alloys, certain types of battery, electronic components and fluorescent or compact fluorescent light tubes (ICRC, 2011). This may be due to their source in the medical waste that was incinerated. The high concentration of Hg in the incinerated as compared to the open pit may be due to the enclose nature of incinerators which facilitated the retention of mercury in the ash residues whiles the open nature of the pit allowed easy vaporisation of mercury. This may imply that people inhaling in smoke from open pit may be exposed to high mercury vapour than from the incinerator. Nunavut Department of Environment (2012) state open-pit burning method has limited or no control over the combustion process, this might have led to the vaporization of mercury during combustion although MFCC had a mean value of 1.64mg/kg in Hg concentration. Chromium (Cr) concentration was the second highest among the four metals that were analysed from the incinerated ash from the two hospitals. Municipal hospital recorded the highest level of Cr with a mean value of 41.75 mg/kg and Regional Hospital had a mean value of 35 mg/kg. Cr is used in tanning, wood preservation and pigments and dyes for plastics, paint and textiles and in some instances Cr alloys (European Commission, 2002). This may mean that the presence of Cr in the incinerated hospital waste ash residue may be due to the presence of plastics in the incinerated waste. Cadmium concentration in the ash was lower but higher than the level of mercury in the medical waste. Municipal Hospital still recorded the highest Cd concentration than the Regional hospital. The trace of Cd in the waste may be from red liner plastic bags used for refuse bins (Hill, 1997) or component in common dyes and thermo and photo stabilizers used in plastics. More so, the high concentration of Cd in the incinerated as compared to the open pit may be due to the enclose nature of incinerators which facilitated the retention of Cd in the ash residues whiles the open nature of the pit allowed easy vaporisation of the metal or possible leached into the soil.

### Environmental and Health dangers posed by studied Heavy metals

The concentration of heavy metals (Pb, Cr, Cd and Hg) in the residues of treated medical waste was compared with Dutch and Danish limit values for maximum permissible levels of heavy metals in good soil quality which is represented in Table 2. This helped to classify the level of heavy metals in the ash residues as harmful or not since the main disposal method of the ash was dumping on land or land filling (World Bank, 1999). The average heavy metal concentrations for Pb, Cd and Hg were above the Dutch and Danish limit values for maximum permissible levels of heavy metals in good soil quality except Cr which was above the Danish limit but within the Dutch limit as in Table 2. Nkonge *et al.,* (2013) research found high concentration for metals like Cr (total), Cd, Pb and Hg from ash residues from incinerated ash. Zhao *et al*. (2008) demonstrated that bottom ashes from medical incinerators with heavy metal residues if not properly disposed of could leach from the ashes and pollute the environment. As most of these pollutants are persistent, probably lasting for centuries, they will sooner or later threaten the water table and aquifers where their removal would be near impossible and they are known to have high leachability (British Society of Ecological Medicine, 2008). Allowing this to take place is an abdication of our responsibility to future generations.

**Table 2. Comparison of Heavy metals limit values for good Soil quality with Tested results**

| Heavy metal | Limit values for good quality soil (mg/kg) | | Heavy metals from the study |
|---|---|---|---|
| | The Netherlands (1998) | Denmark (2000) | - |
| Lead | 85 | 40 | 108.59 |
| Chromium | 100 | 30 | 33.1 |
| Cadmium | 0.8 | 0.5 | 2.11 |
| Mercury | 0.3 | 0.5 | 2.5 |

Goyer (1986) indicated that epidemiological studies have shown that low level exposure of foetus and developing child may lead cause damage to the learning capacity and the neuropsychological development in children. In humans, Pb can result in a wide range of biological effects depending upon the level and duration of exposure. Lead has been shown to have effects on haemoglobin synthesis and anemia, kidney damage low sperm morphology and count in males, in females, some adverse pregnancy outcomes have been attributed to lead (Hsu *et al.,* 1997). In the environment lead binds strongly to particles, such as soil, sediment and sewage sludge and also due to the low solubility of most of its salts, lead tends to precipitate out of complex solutions (EU, 2002). It does not bio accumulate in most organisms, but can accumulate in biota feeding primarily on particles, *e.g.* mussels and worms (Duffus, 2002; EU, 2002). Like in humans, lead may accumulate in the bones (EU, 2002).

Cr is necessary for the metabolism of insulin. It is also essential for animals, whereas it is not known whether it is an essential nutrient for plants, but all plants contain the element (EU, 2002; WHO, 2008). Cr is associated with allergic response such as asthma and dermatitis in sensitized individuals. People who work with material containing mere traces of chromium salts are more at risk than workers who occasionally come into contact with high concentrations of chromium salts. Cadmium accumulates primarily in the kidneys, and its biological half-life in humans is 10–35 years (WHO, 2008). Its accumulation may lead to renal tubular dysfunction, which results in increased excretion of low molecular weight proteins in the urine which is generally irreversible (WHO, 2011).

## CONCLUSION

The study revealed varied heavy metals concentrations in the ashes from the incinerated and open-pit burnt hospital waste. From the incinerators, the studied heavy metals were found to be present in the decreasing order (Pb >Cr >Hg >Cd) of concentration. The same trend was observed for the ashes from the open-pit burnt hospital waste. Generally the concentrations of the heavy metals from the incinerated ash were higher than the counterpart from the open-pit ash, with Pb showing some statistical difference from the t-test analysis. Most of the metal analysed were above the permissible concentration limits for Dutch and Denmark for good soil quality. The study concluded that the high level of heavy metals in the ashes of incinerator and the open-pit burnt hospital waste should be properly disposed of at special cells at landfill sites. Indiscriminate disposal of such waste residue could leach heavy metals into both surface and groundwater which will affect water quality. Most of the studied metals have high environmental effects on human health and the ecological system hence it should be given the required priority it deserves by policy makers and other stakeholders. Policy or guidelines to regulate the disposal incinerated ash residues from hospitals should be developed, disseminated and enforced by the Environmental Protection Agency of Ghana. Research on ecological risk assessment associated with dumping of the incinerated ash is recommended for future studies.

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