Heavy Metal Pollution from Hospital Waste Incinerators: A Case Study from Al-Muthanna Province, Iraq

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Abstract Waste incineration (WI) is the most popular method of hospital waste (HW) disposal in many developing countries. Most hospitals generate large quantities of toxic and persistent waste, which are managed by burning in incinerators. Basically, high concentrations of heavy metal in the food chain are generated from ash residue after burning process. As a result, these concentrations lead to harmful effects on the public health as well as environment. This study aims to investigate the concentrations of heavy metal in the ash of incinerated waste HW1 and HW2 that generated in two hospitals at Samawah and Rumaitha cities, respectively. Ash samples were collected within three months from medium and small incinerators. The concentrations of Cd, Cr, Cu, Pb, Fe and Zn metals were measured using Atomic Absorption Spectrometer (AAS). The concentrations of heavy metal were sorted in descending order as follows: Fe, Zn, Ni, Cu, Pb, Cr and Cd. For both hospital waste, the Fe level was ranged between 76.6 and 25.3 μg/g while other metal levels were varied as follows: Cd (4.6-1.4 μg/g), Zn (35.6-5.6 μg/g) and Cu (17.2-4.0 μg/g). The concentration of Pb in HW2 was found relatively higher than in HW1. The concentration of Pb was varied as (21.6-7.5 μg/g) in HW2 and (15.6-5.4 μg/g) in HW1. Whereas the Cr and Ni concentrations were found as (14.7-1.1 μg/g) and (6.717-3.3 μg/g) in HW1 and HW2, respectively. According to the EPA Law, the concentrations of all samples exceeded the maximum permissible heavy metal levels and can be classified as toxic and risky levels.

1. Introduction

It is generally agreed that the waste amount is worldwide problem [1]. Hospital waste (HW) is mainly clinical and medical waste including identifiable human body parts, blood products, pharmaceuticals, unwanted microbiological stocks, human tissues, sharps, used dressings and bandages. These contents may result in disease, soil, groundwater, surface water and air pollution if they are not treated or managed [2, 3]. All these waste may consist of hazard radioactive, contagious and toxic materials. According to the World Health Organization (WHO), hospital waste is in the second place after radioactive waste in causing dangerous infection, physical injury and adverse effects to the public health and environment as well [4, 5]. Therefore, it is necessary to take into consideration that HW must be managed and disposed with a safe method that result in less harmful or negative impacts as much as possible to the humans and surrounding environment.

The appropriate disposal method of this hazard waste requires a developed system for waste management by following the regulation laws. Waste incineration is mostly the main strategy used in
treating hospital waste in many developing countries, for example, Iraq. This strategy has advantages such as killing pathogens and reducing waste volume and weight in approximate by 95% and 75%, respectively. However, it leads to generate ash residue as a result of burning process [6, 7]. On the other hand, other methods such as using of autoclave, microwave, and recycling HW consider useful and significant methods to mitigate health and environment concerns in the developed countries including the US and UK [8, 9].

The processing of residue materials, commonly known as bottom or fly ashes, results in increasing the amount of heavy metals (such as Cr, Cd, Pb, Hg, Zn and other metals) and discharging toxic gases to the atmosphere (such as SO2, NO2, CO2, CO, … etc.). This is because that various consumer goods are manufactured from iron, lead, cadmium and copper. For example, Lead and its compounds are widely used as additives in plastics (such as PVC stabilizers), paints, glazes and welding preparations. As well, Cadmium is used as a PVC stabilizer and a pigment [20]. Nickel and Cadmium are used in batteries and other metal plating applications. Iron is the fourth most common element that found in the crust of Earth. It is considered as one of the stainless steel components that include an alloy of Iron, Carbon, Chromium, Silicon, Molybdenum and Nickel metals.

In addition, incinerated HW bottom ash includes inorganic and organic compounds that can pollute the atmosphere if they have not disposed properly and may harm the public health such as causing gastrointestinal defects, acute respiratory syndromes and different types of cancer [10-15]. Recently, incinerated bottom ash management has been considered under reviewing and enforcement rules because of these environmental concerns. Researchers from China indicated that high concentrations of metal salts (such as K, Ca, Mg, Al, Fe, and Na) were found in the HW ashes and concentrated between 1.8 and 315 g/kg. Moreover, heavy metal concentrations including Ni, Bi, Ti, Sb, Pb, Sn, Mn, Zn, Cr, Sr, Cu, Cd, Ba, As and Ag were found to be higher in the fly ash samples and ranged with (1.1–121,411 mg/kg) [16].

In this study, samples were obtained from two hospital incinerators in the province of Al-Muthanna to examine Pb, Cr, Cd, Ni, Cu, and Zn concentration in the incinerated waste ash. The concentrations of such chemical elements were measured based on of Atomic Absorption Spectrometry (AAS) technique. Next sections will describe the methodology and results.

2. Methodology

This section includes description of study area and method of data collection as well as sample preparation.

2.1 Study area

Two hospitals in Al-Muthanna province were visited to collect samples of hospital waste (HW). The first visit was to Hussein Teaching hospital waste incinerator (HWI-1) located at Samawah city and the second was to Rumaitah hospital waste incinerator (HWI-2) located at Rumaitah city to the north of Samawah city. Incineration processes are implemented based on the collected quantities of hospital waste. The descriptions and operation characteristics of the two incinerators in the visited hospitals are presented in Table 1. Additionally, Figures 1 shows the location of visited hosiptals in Al-Muthanna province, whereas Figure 2 shows the incinerators of the two visited hospitals.
Table 1: Details of waste incinerators in the two visited hospitals

| Hospital incinerator | HWI-1                  | HWI-2                  |
|----------------------|------------------------|------------------------|
| Type of incinerator  | Medium-scale, one chamber incinerator, operating since 1985, no air pollution control devices (APCDs) | Small-scale, one chamber incinerator, operating since 1993, no air pollution control devices (APCDs) |
| Combustion temperature (°C) | 700-800 | 300-400 |
| Ash type             | Bottom ash             | Bottom ash             |
| Fuel used            | Diesel oil             | Diesel oil             |
| Capacity of incinerator | 60-80 kg/hr | 50 kg/hr |
| Type of ash disposal off | Landfill              | Landfill              |
| Type of loading waste | Manual                 | Manual                 |

Figure 1: A screenshot of Al-Muthanna province shown two hospitals (Source: Google maps)

2.2 Sample collection and preparation

In the hospitals being investigated, non-infectious, infectious and sharps waste are sent to incinerators. Over three months (May-July 2019), twenty four samples of HW ash (HW1 and HW2) were obtained from two incinerators in the two visited hospitals. Table 2 presents different type of incinerated waste ash that selected for data collection purposes.
Figure 2: The visited incinerators in two hospitals in Al-Muthanna province

Table 2. Summary of HW data collected from two hospitals visited in the current study

| Types of HW         | Details of HW                                                                 |
|---------------------|-------------------------------------------------------------------------------|
| Infectious garbage | Wasted blood, bags, body tissues, dextrose, bandages filled with infectious fluids, used syringes, blood strips for testing glucose. |
| Non-infectious waste| Papers and non-bacterial waste.                                               |
| Sharps              | Surgical tools and needles from broken syringes.                              |

Around 100 g of bottom ash was selected from hospital incinerators. One sample was taken per week from HW1 and HW2 individually. The samples were collected from the bottom ash and placed in triplicate plastic bags. Then, they were transported to the laboratory of the Ministry of Science and Technology/ Environmental Research/ Food Pollution Department in Baghdad/ Iraq for heavy metal analysis purpose. The collected ash samples were air-dried at laboratory room temperature of 27°C about 3 to 4 days.
One gram of the dried sample was weighed and transferred to an acid-washed, round bottom flask containing 10 cm³ of nitric acid concentrate. The mixture evaporated steadily on a hot plate for an hour. Before heating and putting on a hot plate, each obtained solid residues was digested for 10 minutes at room temperature with a 3:1 concentrated HNO₃ and HClO₄ mixture. Next, the mixture was put on a hot plate and heated steadily until the HClO₄ fumes shown fully evaporation to maintain a fixed temperature of 150 °C for five hours in approximate [17, 18]. After cooling the mixture within a room temperature, it was filtered into 50 cm³ volumetric flask by using Whatman filter paper (No.1). The next step is to make a standard mark with deionized water to recover any residual metal after rinsing the reacting vessels. Then, the filtrate was kept ready for examination in pre-cleaned polyethylene storage bottles. Atomic Absorption Spectrometry (AAS), with specifications of sensitivity 0.1 ppm/SHIMADZU-AA7000/ Made in Japan, was used to measure the concentration of heavy metal in the solution of each sample in the laboratory. The following metals: Zn, Ni, Cd, Pb, Cu, Cr and Fe were directly quantified by the AAS.

3. Results and discussion

The results of heavy metal concentrations in HW collected from two hospital incinerators in Al-Muthanna province over 12 weeks can be shown in Figure 3. These findings show the risk of concentrations of ash residues that produced by using the method of incineration. During the incineration process, heavy metals are not eliminated but are merely accumulated in the ash residues to high levels in the atmosphere or distributed from the incinerator stack into the surrounding area. In the current analysis, metal emissions from the stack were not covered, but may be highly important. Lead and Cadmium are both metals that are extremely toxic. For instance, exposure of humans and animals to high levels of Lead might result in various adverse effects on kidney function, reproduction and growth [19]. The analysis reveals that the heavy metals of Fe, Zn, Ni, Cu, Pb, Cr and Cd were classified from the highest to lowest concentration. Researchers from Taiwan [20, 21] categorized the levels of different heavy metal collected from ash residues from solid waste incinerators and compared to the requirements of Environmental Protection Genetics (EPA) as shown in Table 3.

| Metal | Taiwan study [20] | Taiwan study [21] | US EPA Standards |
|-------|------------------|------------------|-----------------|
| Zn    | 1-85             | 25.8             | 5.0             |
| Ni    | 1-78             | 0.124            | 0.7             |
| Cd    | 1-29             | 0.470            | 0.005           |
| Pb    | 1-37             | 10.9             | 0.015           |
| Cu    | 6-86             | 1.3              | 1.3             |
| Cr    | 1-70             | 0.863            | 0.1             |
| Fe    | 1-74             | 21.5             | 4.0             |

As shown in Figure 3a, the highest concentration of Fe from HW1 and HW2 ranged between 76.6 and 25.3 µg/g. This was lower than the reported range in previous study [17] that founded to be ranged from 193,462 to 581,002 µg/g. However, due to the highest melting point of iron (1,493 °C), Fe metal is the main component of medical sharps such as needles, hypodermic needles, blades, scalpels and others. Therefore, the highest concentration of Fe may occur due to a high quantity of its residue. As a large amount of Zn causes nausea, stomach cramps and vomiting, Zn is one of the dangerous heavy metals that can be found in medical waste. Also, it considers a reason of causing damage to the pancreas,
anemia and lower cholesterol levels (beneficial cholesterol) of high-density lipoprotein. A short-term illness called metal fume fever, particularly found in bandages or needles, can be resulted by breathing large quantities of Zn. As shown in Figure 3b, the Zn concentration varied from 35.6 to 5.6 μg/g. The maximum observed level was lower than the amount of 85 μg/g that was reported by other researchers as shown previously in Table 3. The concentration of one Zn sample was within the required US EPA limits, as shown in Figure 3b.

Ni is another toxic heavy metal that was investigated in the current work. The dust and fumes of Nickel Sulfide are known as potentially carcinogenic. As presented in Figure 3c, the Ni concentration was varied from 17 to 3.3 μg/g. The reported value was 78 μg/g in previous studies presented in Table 3, which is considered higher than the obtained value in this study. The Ni concentrations were exceeded the appropriate levels in comparison with the US EPA regulations.

Concentrations of Cr were ranged between 14 and 1.1 μg/g (see Figure 3d). Basically, plastics, paint and textiles are made from Cr and its alloys for tanning, wood protection and pigments and dyes. This means that the presence of Cr may refer to existence of plastics in the incinerated hospital waste ash residue.

Another metal such as Pb was varied from 21.6 to 5.4 μg/g, while it was ranged between 7,400 and 19,000 μg/g in a previous study [22]. Pb concentration was observed to be lower in certain samples of HW1 than in HW2 samples (see Figure 3e). The reasons for this are due to type of incinerated pollutants and the difference in burning temperature of incinerators at the two visited hospitals. Since Pb is an instable element, its concentration will remain in residue even at lower temperature as indicated by Tufail et al. [6]. Most incinerated sharps consist of plastic syringes and needles and therefore it is usually expected that Pb content was high. In addition, burned sharps were often mixed with other combustible waste that might probably contribute in existing of Pb content within ash residue. Since the melting point of Pb is 328 °C which is lower than the temperature of incinerator (550-950 °C), this can be another explanation of high Pb levels. As a result, Pb compounds can be melted and adsorbed on the bottom ash surface area during the incineration process [18].

Concentrations of Cu was varied 17.2 to 8.9 μg/g for HW2 and between 9.9 and 4.0 for HW1. These amounts are extremely lower compared to amount reported in previous study [20]. Figure 3f shows that HW2 ash samples contained higher concentrations of Pb and Cu than HW1 samples. This is due to incinerated colored plastic content. In addition, hospital’s infectious and non-infectious waste are wrapped in colored plastic bags before sending to incinerator. The heavy metals that found in hospital waste are toxic materials and come from various items such as accessories made from plastic, Lead batteries, … etc. [16, 23, 24]. Moreover, heavy metals dispersed in plastic contents within small quantities then accumulated in the bottom as ash residues following incineration. The plastic pigment includes highly toxic heavy metals such as Cu, Pb, Cr and Cd. It was found that use of colored plastic in HW1 is relatively high, so the concentrations of Pb, Cd and Cr are relatively lower than their contents in HW1 [10, 25, 26]. In all incinerated ash samples, the measured concentration of Cd is the lowest among other examined elements. Although it is the primary constituent of plastics, Cd is a vastly unstable metal that sublimates into the atmosphere. As shown in Figure 3g, the concentration of Cd was decreased in the incinerated bottom ash of the hospitals in the current study. This phenomenon was verified by Lombardi et al [27].

In the incineration process, heavy metals are not dissolved but merely concentrated in the remains of ash, or spread from the incinerator stack over the surrounding area. Instead of addressing the issue of waste, excessive incineration of waste produces new and more risky materials. Heavy metals in the ash residues are more soluble and accessible to the atmosphere directly. Therefore, they are critical materials [16, 24]. In Iraq, there is no local statutory limit or guideline relating to heavy metal amounts in the bottom ash of incinerators. Based on US EPA requirements for heavy metal contents in incinerated ash, the mean concentration of Pb in the study samples was found to be higher than the acceptable limit, as shown in Figure 3e.

Incinerated ash of HW is dumped into the landfill. While polluted fine ash is randomly dumped on a property, dust dispersal can be more risky. Additionally, there will be an opportunity to increase heavy
metal concentrations in the soil following the rainfall [28-30]. The EEA (European Environment Agency) proposed in the document on hazardous substances in waste that all types of ashes must be pre-treated before disposing. The approach of using cement as a stabilizer prior to dumping may decrease the risk of ash-to-environment erosion of heavy metals and other hazardous chemical effects [31].

(a) Concentration of Fe in HW1 and HW2

(b) Concentration of Zn in HW1 and HW2

Figure 3: Variation of heavy metal concentrations over 12 weeks in the incinerated ash samples
Figure 3: Variation of heavy metal concentrations over 12 weeks in the incinerated ash samples (continued)
4. Conclusions and Recommendations

Waste management study was implemented in two visited hospitals at Samawah and Rumaitha cities located in Al-Muthanna province. Waste infectious, non-infectious and sharp waste are burned inside these hospitals’ incinerators. The investigated concentrations of heavy metal were found to be presented in the descending order as follows: Fe, Zn, Ni, Cu, Pb, Cr and Cd. The ash was tested for toxic heavy metals. Since most of these contaminants are likely existed for decades, they would pollute the atmosphere where it will be almost difficult to eliminate their effects since they seem to be highly leachability [32, 33]. Heavy metal concentrations at hospitals waste vary with respect to burning period, time, incinerator type, burning temperature, waste type and quantities… etc. The concentrations of heavy metal in all collected samples were extremely higher than the normal EPA values except one sample of Zn. If the incineration method is the only following method that used for disposing hospital waste, it is important to remind that the produced bottom ash from incinerated waste should be properly disposed in order to control the contamination of area. It is also necessary to recommend certain alternative methods that are less risky than incineration such as wet and dry thermal treatment, microwave irradiation and land disposal.
References

[1] M.M.A. El-Salam, Hospital waste management in El-Beheira Governorate, Egypt, Journal of environmental management 91 (2010) 618-629.

[2] P. chetan Vitthal, C.S. Sanjay, B.R. Sharma, M. Ramachandran, Need of Biomedical Waste Management in Rural Hospitals in India, Int. J. Pharm. Sci. Rev. Res 35 (2015) 175-179.

[3] A. Ferdowsi, M. Ferdosi, Z. Mehrani, P. Narenjkar, Certain hospital waste management practices in Isfahan, Iran, International journal of preventive medicine 3 (2012) S176.

[4] A. DenBos, A. Izadpanah, Building capacity for comprehensive medical waste management in Asia, EM The Urban Environment 18 (2002) 20.

[5] S. Manyele, H. Anicetus, Management of medical waste in Tanzania hospitals, Tanzania Journal of Health Research 8 (2006).

[6] M. Tufail, S. Khalid, Heavy metal pollution from medical waste incineration at Islamabad and Rawalpindi, Pakistan, Microchemical Journal 90 (2008) 77-81.

[7] C.R. Brunner, Hazardous waste incineration, (1993).

[8] M. Yan, X.D. Li, S.Y. Lu, T. Chen, Y. Chi, J.H. Yan, Persistent organic pollutant emissions from medical waste incinerators in China, Journal of Material Cycles and Waste Management 13 (2011) 213.

[9] F. Nemathaga, S. Maringa, L. Chimuka, Hospital solid waste management practices in Limpopo Province, South Africa: A case study of two hospitals, Waste management 28 (2008) 1236-1245.

[10] A.A. Mohammed, H.M. Selman, Liquid surfactant membrane for lead separation from aqueous solution: Studies on emulsion stability and extraction efficiency, Journal of Environmental Chemical Engineering 6 (2018) 6923-6930.

[11] G.V. Patil, K. Pokhrel, Biomedical solid waste management in an Indian hospital: a case study, Waste management 25 (2005) 592-599.

[12] Y.-C. Jang, C. Lee, O.-S. Yoon, H. Kim, Medical waste management in Korea, Journal of environmental management 80 (2006) 107-115.

[13] S. Singh, V. Prakash, Toxic environmental releases from medical waste incineration: a review, Environmental monitoring and assessment 132 (2007) 67-81.

[14] E. Gidarakos, M. Petrantonaki, K. Anastasiadou, K.-W. Schramm, Characterization and hazard evaluation of bottom ash produced from incinerated hospital waste, Journal of hazardous materials 172 (2009) 935-942.

[15] M. Tsakona, E. Anagnostopoulou, E. Gidarakos, Hospital waste management and toxicity evaluation: a case study, Waste management 27 (2007) 912-920.

[16] L. Zhao, F.-S. Zhang, K. Wang, J. Zhu, Chemical properties of heavy metals in typical hospital waste incinerator ashes in China, Waste Management 29 (2009) 1114-1121.

[17] R. Patcharin, A study of heavy metals in bottom ash from medical waste incinerator in Nakhon Ratchasima Municipality, สํานัก วิชา วิศวกรรมศาสตร์, มหาวิทยาลัยเทคโนโลยีสุรนารี, 2002.

[18] J.A. Saria, Levels of Heavy Metals in Bottom Ash from Medical Waste Incinerators in Dar es Salaam.

[19] J.L. Pirkle, R.B. Kaufmann, D.J. Brody, T. Hickman, E.W. Gunter, D.C. Paschal, Exposure of the US population to lead, 1991-1994, Environmental health perspectives 106 (1998) 745-750.

[20] S.-J. Chen, M.-C. Hung, K.-L. Huang, W.-I. Hwang, Emission of heavy metals from animal carcass incinerators in Taiwan, Chemosphere 55 (2004) 1197-1205.

[21] C.-Y. Chang, C.-F. Wang, D. Mui, M.-T. Cheng, Characteristics of elements in waste ashes from a solid waste incinerator in Taiwan, Journal of hazardous materials 165 (2009) 766-773.

[22] O. Hjelmar, Waste management in Denmark, Waste Management 16 (1996) 389-394.
[23] R. Kumar, D. Patel, R. Kumar, A survey of trace metals determination in hospital waste incinerator in Lucknow City, India, Online Journal of Health and Allied Sciences 3 (2004).
[24] M. Adama, R. Esena, B. Fosu-Mensah, D. Yirenya-Tawiah, Heavy metal contamination of soils around a hospital waste incinerator bottom ash dumps site, Journal of environmental and public health 2016 (2016).
[25] A. Krishna, P. Govil, Assessment of heavy metal contamination in soils around Manali industrial area, Chennai, Southern India, Environmental Geology 54 (2008) 1465-1472.
[26] O. Huerta-Pujol, M. Soliva, F. Giró, M. López, Heavy metal content in rubbish bags used for separate collection of biowaste, Waste management 30 (2010) 1450-1456.
[27] F. Lombardi, T. Mangialardi, L. Piga, P. Sirini, Mechanical and leaching properties of cement solidified hospital solid waste incinerator fly ash, Waste Management 18 (1998) 99-106.
[28] L. Herngren, A. Goonetilleke, G.A. Ayoko, Understanding heavy metal and suspended solids relationships in urban stormwater using simulated rainfall, Journal of environmental management 76 (2005) 149-158.
[29] A. Sainz, J. Grande, M. De la Torre, Characterisation of heavy metal discharge into the Ria of Huelva, Environment International 30 (2004) 557-566.
[30] S. Singh, F. Tack, D. Gabriels, M. Verloo, Heavy metal transport from dredged sediment derived surface soils in a laboratory rainfall simulation experiment, Water, air, and soil pollution 118 (2000) 73-86.
[31] P. Bosch, The European Environment Agency focuses on EU-policy in its approach to sustainable development indicators, Statistical Journal of the United Nations Economic Commission for Europe 19 (2002) 5-18.
[32] J. Thompson, H. Anthony, The health effects of waste incinerators, Journal of Nutritional & Environmental Medicine 15 (2005) 115-156.
[33] A. Honor, The Health Effects of Waste Incinerators, The 4th Report of the British Society for Ecological Medicine (2005).