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Heavy metal pollution from medical waste incineration at Islamabad and Rawalpindi, Pakistan

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ABSTRACT

Hospitals in Pakistan generate a large quantity of waste which is mainly managed by burning in incinerators. Burning of medical waste pollutes the environment by fly ash and toxic metals in the incinerated ash. Information regarding generation of heavy metals from incineration of medical waste is rare in Pakistan. The infectious waste generated in the hospitals of Islamabad (the capital of Pakistan) and Rawalpindi (the twin city of Islamabad) is disposed through burning in incinerators. The objective of this study was to investigate the concentration of heavy metals remained in ash of the incinerated waste. Ash samples from 5 incinerators were collected for 5 weeks and 25 samples were analyzed for investigation of toxic heavy metals in them. The concentration of Cd, Cr, Cu, Pb and Zn was found using FAAS (flame atomic absorption spectrometer). The amount of these metals varied from day to day, hospital to hospital, and incinerator to incinerator depending upon the medical waste generated in the hospitals. The concentration of Pb and Zn was found relatively higher than that of other constituents in the waste. Average concentration of Pb was 3.9, 3.2 and 4.6 µg/g whereas that of Zn was 6.6, 5.3 and 6.7 µg/g respectively in the waste from Hospital 1, Hospital 2 and Hospital 3. The main source of these metals in the incinerated ash was the presence of PVC (poly vinyl chloride) material in the waste. A wide variation in concentration of metals was due to diversity in the initial waste composition, design of the incinerator, and operating conditions.

1. Introduction

Waste generation has increased considerably worldwide in the last few decades [1]. Medical waste in particular has increased greatly because hospitals use relatively more disposable items, such as syringes, cutlery, food trays, bed pans, etc. [2]. Hospitals produce a tremendous amount of medical waste that is defined as any solid waste which is generated as a result of patient diagnosis, treatment, or immunization of humans or animals, in related research, and the waste capable of producing infectious disease [3]. Medical waste can consist of infectious, radioactive, and toxic substances from hospitals, laboratories, and clinics. These include sharps (syringes and needles), blood products, human tissues, body parts, pharmaceuticals, cytotoxins, and heavy metals, in addition to the item of general use such as paper, food, plastics etc. According to WHO (World Health Organization), the waste produced by hospitals carries a higher potential for infection and injury than any other kind of waste [4]. Hospital waste is considered dangerous because it may possess pathogenic agents and can cause undesirable effects on human health and the environment [5].

It is necessary that all medical waste must be disposed in a manner which is least harmful to human beings. Medical waste management is of a high priority environmental concern in developing countries of the world [4] because poor management of medical waste causes environmental pollution and health problems in terms of proliferation of disease by viruses and micro-organism, as well as contamination of ground water by untreated medical waste in landfills [6]. The improper disposal of infectious waste can pose a significant threat to public health and the environment [7]. The careless disposal of sharps that are scavenged and reused, may lead the induction of hepatitis B, hepatitis C, HIV and other possible infectious diseases to the exposed population [8].

The massive volume of the medical waste in many countries of the world is mostly reduced through incineration that leads to the generation of ash as a new type of waste. The combustion process destroys pathogens and reduces the waste volume by ~95% and weight by ~75% [9]. The incineration of hospital wastes not only releases toxic gases (CO, CO_2, NO_2, SO_2 etc.) into the atmosphere but also leaves solid material as residue which as bottom and fly ashes increases the level of heavy metals, inorganic salts and organic compounds in the environment [10]. Bottom ash is an un-avoidable by-product of incineration which is concentrated of heavy metals, which can be used for the land filling and block making. Metals are not destroyed during incineration and are often released into the

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environment, along with ash, in more concentrated and dangerous forms. High temperature combustion evaporates some toxic metals from waste products consisting of batteries, paints and certain plastics. The tiny metal particles suspended in air increase the risk of inhalation related diseases [11]. The environmental group of Greenpeace detected a high concentration of toxic heavy metals in ash of a hospital incinerator and revealed that the public is exposed to dangerous pollutants of the incinerator in many countries of the world [12].

In Pakistan, normally a large volume of hospital waste is burned in incinerators; therefore we selected 3 hospitals (two hospitals in Islamabad and one in Rawalpindi) whose infectious waste is managed by burning in 5 incinerators. Ash samples were collected from the incinerators of the hospitals under study for the investigation and quantification of Cd, Cr, Cu, Ni, Pb, and Zn in the incinerated waste ash. The technique of atomic absorption spectrometry was employed to determine the concentration of the elements of interest.

2. Experimental

Medical waste of three hospitals in the cities of Islamabad and Rawalpindi, Pakistan was studied. The hospitals under consideration were given names as Hospital 1 (H_1), Hospital 2 (H_2), and Hospital 3 (H_3). Two hospitals H_1 and H_2 are in Islamabad, whereas H_3 is in Rawalpindi. Hospital 1 is in the public sector, has three incinerators and Hospitals 2 and 3 are in the private sector, having one incinerator each. The type of the waste generated in these hospitals is presented in Table 1. The strategy of waste collection, segregation and incineration is described in Table 2. The non-infectious waste is handed over to the municipality workers while the infectious waste and sharps are sent to incinerators in the hospitals under study.

Twenty five ash samples were arranged from five incinerators of the concerned hospitals. Each of the ash samples was about 1 kg in weight that was dried at room temperature, and passed through a strainer to remove the metal and glass pieces in ash. About 200–300 g of every sample was packed in polyethylene bags. The bags were brought to the Analytical Laboratory of Environmental Sciences Department, FJWU (Fatima Jinnah Women University), Rawalpindi, Pakistan.

The samples were pulverized and passed through a 5 mesh size sieve. The ash was ground to powder using a mechanical grinder, mixed with a blender, and taken to the analytical facility. The powered samples were shifted into plastic bottles which were labelled and properly catalogued. One gram of every sample was taken into 100 ml beaker, to which 3 ml HNO_3 was added and 1 ml concentrated HCl was mixed. The samples were digested for 20–25 min by placing on a hot plate at 100 °C and mixed with a magnetic stirrer at 4 rps. After cooling the samples at ambient temperature, 100 ml distilled water was added into the solution. Solution of every sample was filtered separately for the analysis of required heavy metals.

Heavy metals in the solution of every sample were analyzed by Flame Atomic Absorption Spectrometer (FAAS) (Model SPECTR*AA* 220, Varian, Australia). The calibration was validated using quality control standard, prepared internally from different reagent stocks. Each element was analyzed against specific wavelength and slit width. The accuracy and reliability of the analysis were checked by applying standard reference material BCR 032 (rock standard, IRMM, Europe). Same experimental procedure was followed for the digestion of standard as was adopted for the ash samples. Standard addition method was used to check the recovery efficiencies of the samples.

Table 1
Type and components of waste generated in the hospitals under study

Waste type	Waste components
Infectious waste	Wasted blood, body tissues, dextrose, bags, used syringes, bandages soaked in infectious fluid, blood glucose test strips.
Sharps	Used needles from broken syringes.
Non-infectious waste	Papers and other no-bacterial waste.

Table 2
The strategy of waste collection, segregation and incineration

Waste collection and segregation	Incinerators
Hospital 1	
• Plastic bags for waste collection.	• Three double chambered incinerators, in operation since 1993.
• Blue bin for infectious waste.	• First chamber temperature 400–500 °C.
• Light yellow bin for non-infectious waste.	• Secondary chamber: works as dry scrubber.
• Red bin for sharps.	• Capacity: 60–80 kgh−1.
	• Loading and de-loading: Manual.
	• Ash is simply disposed off as heap at nearby plot.
Hospital 2	
• Coloured bins are placed in every room.	• One double chamber incinerator, operating since 2002.
• Waste is segregated at source.	• First chamber temperature 800 °C.
• Blue bin/bag for non-infectious waste.	• Second chamber temperature 1200 °C.
• Red bin/bag for infectious waste.	• Capacity: 50 kgh−1.
• White bin/bag for sharps.	• Loading and de-loading: Manual.
	• Ash is disposed off in land fill.
Hospital 3	
• Coloured bins are placed in every corridor of hospital l.	• Three chamber incinerator of an oil refinery.
• Blue bin/bag for non-infectious waste.	• Primary chamber temperature 850 °C.
• Red bin/bag for infectious waste.	• Secondary chamber temperature 1050 °C.
• White bin/bag for sharps.	• Tertiary chamber: works as dry scrubber.
	• Capacity: 50 kg−1.
	• Loading and de-loading: Manual.
	• Ash is used for building blocks.

Table 3
Concentrations of heavy metals in incinerated medical waste ash from three hospitals

Serial number (Sr. No.)	Sample identity	Zn (μg/g)	Ni (μg/g)	Cd (μg/g)	Pb (μg/g)	Cu (μg/g)	Cr (μg/g)
1.	$H_1I_1W_1$	6.8	2.723	0.0537	2.9808	2.1844	0.628
2.	$H_1I_1W_2$	9.9338	2.644	0.07	12.0835	10.7322	0.7925
3.	$H_1I_1W_3$	10.8978	3.1521	0.0933	2.3611	1.9282	0.9976
4.	$H_1I_1W_4$	2.6517	0.3911	0.3159	1.6014	1.9589	0.4279
5.	$H_1I_1W_5$	9.5034	2.7463	0.2519	5.0114	1.2063	0.985
6.	$H_1I_2W_1$	1.6913	0.4272	0.4839	1.125	0.1944	0.321
7.	$H_1I_2W_2$	9.3171	0.4989	0.5407	0.592	0.3236	0.8542
8.	$H_1I_2W_3$	2.894	0.5292	1.0434	10.5793	0.2654	0.4151
9.	$H_1I_2W_4$	4.9935	0.4255	0.0925	0.4757	0.2171	0.5293
10.	$H_1I_2W_5$	8.5128	2.5195	0.2598	3.4132	0.792	0.942
11.	$H_1I_3W_1$	5.4756	2.0549	0.1484	1.5903	1.7631	0.7245
12.	$H_1I_3W_2$	7.7053	1.4265	0.173	3.7234	3.95	0.9725
13.	$H_1I_3W_3$	13.6301	0.791	0.0554	1.4911	2.0658	1.0325
14.	$H_1I_3W_4$	1.2962	0.5329	0.2421	1.7536	4.5073	0.2518
15.	$H_1I_3W_5$	4.0708	0.9711	0.1799	11.0388	2.093	0.5259
16.	H_2IW_1	2.2999	0.745	0.1692	2.5213	8.9718	0.3215
17.	H_2IW_2	4.2238	0.8659	0.1856	3.4159	19.1086	0.4298
18.	H_2IW_3	6.2551	0.9251	0.2351	3.2902	10.8935	0.6704
19.	H_2IW_4	7.4291	2.5725	0.1517	3.2192	12.1642	0.6524
20.	H_2IW_5	6.2517	1.6211	0.1729	3.4132	11.993	0.5479
21.	H_3IW_1	9.3178	1.2603	0.1792	6.5359	7.6043	0.9282
22.	H_3IW_2	3.857	0.9457	0.0921	4.7946	2.6347	0.4117
23.	H_3IW_3	8.2576	1.2592	0.1592	4.1208	8.47	0.7252
24.	H_3IW_4	7.9211	1.0079	0.0825	1.9669	2.8034	0.5134
25.	H_3IW_5	3.5991	1.3245	0.1859	5.7925	17.1397	0.4093

H_1 = Hospital 1; H_2 = Hospital 2; H_3 = Hospital 3.
I = Incinerator; I_1 = Incinerator 1; I_2 = Incinerator 2; I_3 = Incinerator 3.
W_1 = Week 1; W_2 = Week 2; W_3 = Week 3; W_4 = Week 4; W_5 = Week 5.