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Original Research Article

Comparative Study of Heavy Metal Contamination at Common Biomedical Waste Treatment and Disposal Sites (Incineration and Deep Burial) in Mumbai, Maharashtra, India

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ABSTRACT

Low level exposure to heavy metals likes, mercury (Hg), cadmium (Cd), arsenic (As), Chromium (Cr), and lead (Pb) which are systemic toxicants known to induce multiple organ damage. All these elements are commonly found in biomedical waste and negligence towards improper handling and management of biomedical waste leads to heavy metal contamination. In present study soil and water samples were collected from two, Common Biomedical Waste Treatment Facilities for three consecutive months. Soil and water samples were analysed for Copper (Cu), Nickel (Ni), Zinc (Zn), Cadmium (Cd), Lead (Pb), Iron (Fe), Total Chromium (TCr), Aluminium (Al), Manganese (Mn), Arsenic (As) and Mercury (Hg) using 'Inductively Coupled Plasma Optical Emission Spectroscopy' and 'Flow Injection Mercury System'. The levels of mercury exceeded the standard limits of 0.01-0.3 mg/kg and 0.001 mg/l in both soil and water respectively. Other elements like Pb, Cr and Cu analysed from soil were comparatively low, whereas elements like Cu, Pb, Fe, and Hg were high raw effluent (i.e. Before treatment), however, after effluent treatment levels of these elements decreased. Significantly improper segregation, management and handling of the BMW on the site have led to increase in mercury levels in effluent. Even after treatment and further reuse/disposal of treated effluent for gardening/ floor washing might have contaminated soil in the premises.

Keywords: Biomedical waste, waste management, heavy metals.

INTRODUCTION

A modern hospital is a complex institute, with multidisciplinary systems which consumes thousands of items in order to deliver medical care. All these products used in the hospital leaves behind a huge pile of unusable and contaminated leftovers which is considered to be biomedical waste. [1] Biomedical waste is of significant concern to public health. According to the data provided by the World Health Organization (WHO), out of the total waste generated in the hospital, 85% of the waste is considered to be general and non-infectious waste, while 15% of the waste is hazardous which includes infectious, radioactive and toxic waste. [2]

Lack of awareness about the health hazards related to biomedical waste, limited training for waste management, absence of knowledge and/or negligence towards the BMW management and disposal systems, leads to accumulation of toxic heavy metals from hazardous biomedical waste into the surrounding environment. Although some of the heavy metals are essential in trace amounts, however, if these heavy metals tend to exceed their standard concentration, they are considered to be toxic to the environment and to human health.

Environmental hazards include leaching of the heavy metals which may lead to contamination of the soil/ground water sources. Heavy metals being absorbed by plants and enter into the food chain. Heavy metals such as Mercury (Hg), Cadmium (Cd), Arsenic (As), Chromium (Cr), and Lead (Pb) found in biomedical waste are considered to be systemic toxicants that are known to cause multiple organ damage. They are also classified as human carcinogens according to the US Environmental Protection Agency and the International agency for Research on Cancer. [3]

Previous studies to evaluate the presence of heavy metals have been carried out from ash obtained from incineration of biomedical waste. However, the soil and water around a biomedical waste treatment facility hasn't been evaluated. In the present study an attempt was made to evaluate the presence of heavy metals from soil and water in and around the two common biomedical waste treatment facilities, where biomedical waste from numerous hospitals around Mumbai and Navi Mumbai are brought for treatment.

MATERIALS AND METHODS

Study area

M/S SMS Envoclean Pvt. Ltd, Govandi, Mumbai and Evergreen Environmental, Uran, Raigad were the two Common Biomedical Waste Treatment Facilities (CBWTFs) considered for the study.

Biomedical wastes from the health care establishments (HCEs) in Mumbai are treated at SMS Envoclean by methods like Incineration, Autoclaving, Shredding, and Effluent treatment. BMW from HCEs situated in Uran are treated at Evergreen Environmental using the methods which include Deep burial, Autoclaving, Shredding.

The consent for visiting and sample collection was obtained from The Maharashtra Pollution Control Board (MPCB), Govt. of Maharashtra.

The SMS Envoclean treatment facility receives approximately 4737kgs/day of BMW from all the health care facilities in Mumbai [4] and approximately 25kgs/day of the BMW is treated at the treatment facility at Uran.

Sample collection

Integrated Soil sample: Integrated Soil samples were collected in sterile Tars on tubes following international standards of manual sampling, which involved minimal use of equipment and collection from 5 different points simultaneously [5] (figure 1 and 2). The collected integrated soil samples were mixed and used as a final sample for further studies. The samples were then stored at room temperature in a dry place.

Grab Water sample: Grab Water samples were collected in sterile Tars on tubes following international standards of manual sampling, which involved minimal use of equipment [5] (figure 1) , from SMS Envoclean Common Biomedical Treatment facility, Govandi. The samples were collected at two different intervals, i.e. before and after effluent treatment.

Location of Sample Collection

Soil and water sample preparation for Metal Analysis using inductively Coupled Plasma Optical Emission Spectroscopy (ICP- OES)

Soil samples were digested using $HNO_3/HCLO_4$ digestion method and water samples were digested using the HNO_3 digestion method as described by Eaton *et al* [5] and analysed using an (ICP-OES) (Thermo Scientific *i* Cap 6000 series).1gram of soil sample was digested with 3ml concentrated Nitric Acid (HNO_3) and Perchloric Acid ($HClO_4$) for 1hr each at 145^0C and 240^0Crespectively. After cooling, the samples were diluted and final volume of 50ml was made by D.W. 100ml water sample was digested with 5ml concentrated

Nitric Acid (HNO_3) by heating till volume reduced to 10ml. After cooling, the sample was diluted with distilled water to make up a volume of 100ml and filtered.

The ICP-OES was calibrated using diluted standard solutions (0.5parts per million-12parts per million).

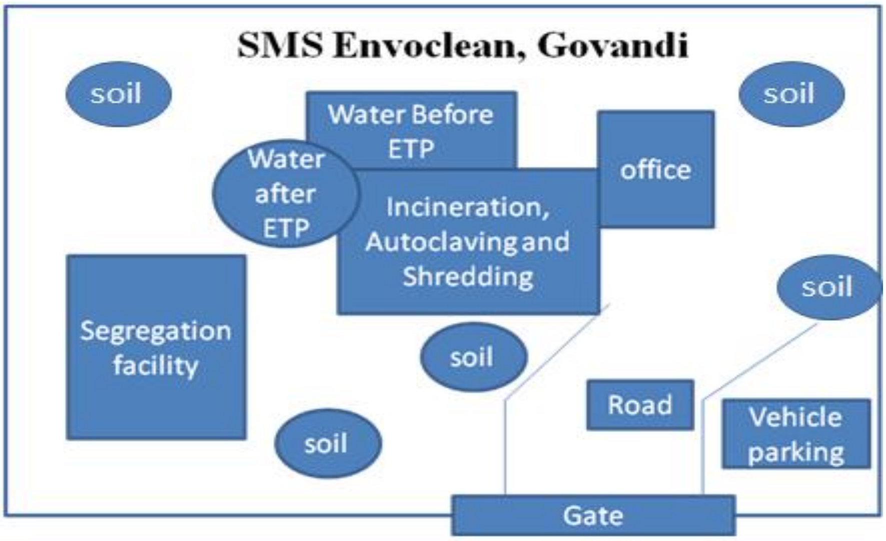

Fig 1: Spot of soil and water sampling from SMS Envoclean Govandi.

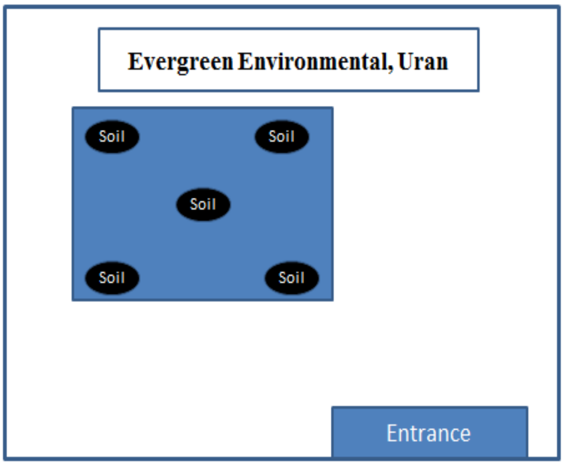

Fig 2: Spot of soil sampling from Evergreen Environmental Uran.

Soil and water sample preparation for Mercury analysis using Flow Injection Mercury System (FIMS)

Soil and water samples were digested for analysis as per method described by Eaton *et al* [5] and analysed on FIMS (Perkin Elmer FIMS100). 1gram of soil sample was mixed with 50ml of distilled water in B.O.D. bottle. 2.5ml of Sulfuric Acid (H_2SO_4) (0.5N) and 1.25ml of HNO_3 (1:1) was added to the mixture. Then 5% Potassium permanganate ($KMnO_4$) was added drop wise until violet colour persists followed by the addition of 4ml of 5% Potassium per sulfate ($K_2S_2O_8$). Bottles were placed in hot water bath for 2 hours at 95^0 C.

FIMS was calibrated using freshly prepared standard solutions of mercury ranging from 10 ppb - 30 ppb. Freshly prepared 3% Hydrochloric acid (HCL) was used as a carrier reagent and 0.2% sodium borohydride was used as the reduction reagent during the analysis.

RESULT

The concentration of heavy metals analysed from soil sample from SMS Envoclean Govandi, was found to be within the normal range, except for Hg (table 1), whereas the concentration of Cu, Pb, Fe, Hg was found to be above permissible limits in raw effluent (i.e. Before treatment) (table 2). While there is a decrease in the concentration of heavy metals after effluent treatment, but the levels of Hg still remained above permissible limits. Significant decrease in the levels of heavy metals after effluent treatment was observed in the month of April due to the use of Poly electrolyte along with carbon and sand filters.

Table 1:- Heavy metal analysis results from soil samples (SMS Envoclean, Govandi)

Month	Heavy metals analysed (mg/kg)										
	Cu	Ni	Zn	Cd	Pb	Fe	TCr	Al	Mn	As	Hg
Feb	9.98	1.94	4.52	BDL	1.34	1061.97	3.55	801.26	13.78	BDL	1.861
March	1.45	1.29	1.63	BDL	0.48	851.17	1.39	735.26	10.03	BDL	1.140
April	2.37	1.5	1.89	BDL	0.62	1153.97	2.02	1040.66	37.15	BDL	1.353

Table 2: Heavy metals analysed from Water samples (before and after ETP)

Water samples before and after ETP treatment												
Month	Sample	Heavy metal analysed (mg/l)										
		Cu	Ni	Zn	Cd	Pb	Fe	TCr	Al	Mn	As	Hg
February	Before ETP	0.109	0.069	5.618	0.015	1.53	2.12	0.091	2.48	0.065	0.01	0.098
	After ETP	0.099	0.016	0.118	BDL	BDL	0.68	0.038	0.3	BDL	BDL	0.003
March	Before ETP	0.15	0.414	1.021	0.044	0.971	0.579	0.31	1.21	0.14	0.03	0.040
	After ETP	0.04	BDL	0.163	0.009	0.029	0.275	BDL	0.02	0.02	BDL	0.003
April	Before ETP	0.10	0.02	1.17	0.01	0.26	0.3	0.018	1.01	0.07	BDL	0.115
	After ETP	0.02	BDL	0.05	BDL	BDL	BDL	BDL	0.36	0.017	BDL	0.011

Table 3: Heavy metal analysis results from soil samples (Evergreen Environmental, Uran)

Month	Heavy metals analysed (mg/kg)										
	Cu	Ni	Zn	Cd	Pb	Fe	TCr	Al	Mn	As	Hg
February	3.56	6.49	0.18	BDL	BDL	893.27	2.93	942.56	11.83	BDL	0.631
March	1.45	7.14	1.83	BDL	BDL	857.67	1.17	945.96	12.91	BDL	0.547
April	1.62	6.05	0.94	BDL	0.03	930.77	1.56	801.46	11.98	BDL	1.178

Similar results for soil sample were observed at Evergreen Environmental Uran, where the concentration of heavy metals analysed was found to be within permissible limits, except for Hg (table 3).

DISCUSSION

The present study was conducted for the span of three months and much variability in the metals concentration was not observed in the soil sample from both the treatment sites, while other studies have shown higher levels of Pb, Cr, Cu, exceeding the permissible limits from incinerator bottom ash. [6] A study by Ephraim *et al.* (2013) from the BMW incineration site and contamination of surrounding agricultural land had shown increases in the concentration of heavy metals like Si, Fe, Cr, Pb. The increase in the concentration of these metals may be because of anthropogenic activity around the incineration site. [7]

Higher concentration of metals in the raw effluent can pose serious threat to the environment. The results obtained in the month of April were indicative of an improved treatment which involved the use of Polyelectrolytes, along with the use of carbon and sand filters. Polyelectrolytes are used in water treatment systems for a variety of applications which includes coagulation, flocculation, ballasted sedimentation, filtration, and sludge conditioning. There are multiple advantages of polyelectrolytes which include more efficient removal of particle organic matter and colour reduced sludge formation, sludge conditioning; and reduced reliance on metal salts. [8] In an analysis report by CPCB, of wastewater, it was observed that the levels of Hg were in the order of 0.1 to 0.5 ug/l, although the values were below the prescribed limits, it was indicative of the occurrence of Hg contamination in the hospitals. [9]

Concentration of Hg was observed on the higher side, than of the permissible limits throughout the study period, indicating the improper handling of Hg at the site of generation of BMW.

According to The Environmental Sound Management guidelines for Mercury by CPCB, Hg is present in almost every HCF for eg: - Thermometer, Sphygmomanometers, Dental amalgam, Esophageal dilators, Feeding tubes, Gastrointestinal tubes, Miller- Abbott tube, Intraocular pressure device, Strain gauge, Urinometer, X-ray machines, Medical batteries, Thimerosal, Barometers, Laboratory chemicals, Vaccines and nose drops. It is estimated that an accidental spillage due to breakage is two thermometers per bed per year. [9] Mercury has a tendency to remain in the environment for a long period of time and is known as a persistent bioaccumulative and toxic (PBT) pollutant.

Most of Hg found in the environment is in organic form, since it is never broken down into the other chemical and harmless forms. Once Hg enters into the environment, it permanently remains by changing its chemical form.

RECOMMENDATIONS

1. Segregation of waste should be done at the source, i.e. health care facilities as per the guidelines issued by the Central Pollution Control Board (CPCB).
2. Mercury waste generated should be categorised under electronic waste (E. Waste) and should be treated with, authorized E. Waste treatment facilities.
3. Treated effluents should not be used for land applications and floor washing.

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