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Assessment of Heavy Metal Contamination in Incinerated Medical Waste

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ABSTRACT

The incineration of medical waste (MW) is a significant alternative way for disposal of this category of waste. Thus nuisance has acknowledged much attention but relatively less attention has been given to bottom ash. Now bottom ash is dumped on the soil which mixes into the soil as diffused pollutant. In this study bottom ash samples were collected from a typical MW incinerator and typical pollutants including heavy metals (Fe, Cr, Cd, Cu, Pb) concentration were examined by following standard extraction and detection procedure. Pollution Load Index, Ecological Risk Index, Enrichment Factor and Geo accumulation Index were applied to assess the level of heavy metal contamination. Co-relation factors of those heavy metals were also established. In our test, the concentration of Cu, Cr and Pb exceeded the tolerable level. The concentration of Cd did not exceed the tolerable level.

Keywords: *Medical waste, incinerator, bottom ash, heavy metal, contamination*

1. INTRODUCTION

The potential risk in healthcare waste management especially in managing medical wastes properly is a concerning issue nowadays [9, 10]. Between 75% and 90% of the waste produced by health care providers is non-risk or general health care waste, and remaining 10-25% of health care waste is regarded as hazardous and may create a variety of health risks [11,9].So it is important to take care of the treatment of medical waste. One of the medical waste treatments used worldwide is medical waste incineration. Incineration is a high temperature dry oxidation process that reduces organic and combustible waste to inorganic, incombustible matter and results in a significant reduction of waste volume and weight [9, 10]. Incinerator ash is divided into two categories: bottom ash and fly ash. Most of the ash is bottom ash that is the residues inside the burner after incineration. Fly ash settles on post burner equipment such as scrubbers. The bottom ash generation depends on the quantities, density, and characteristics of solid waste incinerated. The ash is 22.17% by weight of total waste [9,10].

In a study in New York City the composition of bottom ash was found as carbon 5%, fine ash 34.7%, moisture content 9.9%, glass 36.6%, and metals 13.9%. But when bulky waste such as metals and glass was separated, the composition of ash changed to: carbon 10%, moisture content 9.9%, glass 36.6%, and metals 13.9%. But when they separated fine ash 70%, and moisture content 20.0% [12, 9] Although incineration can reduce the weight of waste by more than 70%, large amounts of combustion residues, especially bottom ash, still remained after incineration [8, 10]. Bottom ash contains toxic heavy metals (chromium, cadmium, lead, arsenic, zinc, and other metals) as well as organic compounds (PCBs, dioxins, benzene, and other cancer causing organics) [9,29].The troublesome level of soil contamination as per soil contamination standard (SCS) [1,3,10], shown in Table 1 along with sediment quality guideline (SQG) [2, 10], is described as the level which is likely to obstruct the health and properties of persons or rearing of animals and plants. [1, 2, 3, 10]

Table 1: Metal Contamination Standard for Soil and Sediment

Heavy metals	SCS		SQG		
	Trouble-some	Counter-measure	Un-polluted	Moderately polluted	Heavily polluted
Cd	1.5	4	-	-	>6
Cu	50	125	<25	25-50	>50
As	6	15	<3	3-8	>8
Hg	4	10	<1	-	>1
Pb	100	300	<40	40-60	>60
Cr	4	10	<25	25-75	>75
Zn	300	700	<90	90-200	>200

Ni	40	100	<20	20-50	>50

2. MATERIALS AND METHODS

Bottom ash samples were collected from a typical incineration facility of Matuail Municipal Waste Landfill Area located in Damra, Narayangong. Six mixed samples were collected from the incinerator in every 1 alternate month. Triplicate analyses of one sample per each kind of MWBA were conducted. The samples were dried at 105^0 C for 24 h and then ground to a particle diameter of <0.25mm in an agate mortar for analysis of heavy metals [3, 10, 17, 18]. The pH was measured in solutions after 24 h of agitation with distilled water at a liquid to solid ratio of 10. To detect the pH of the ashes, at first ashes were taken in to distill water (DW) [Ash: DW=1:10] in a biker. Then it was shook properly. After that, this mixture was filtered. The pH of DW was measured with the help of pH meter and it was found "7".Then pH of the filtered solution was measured. The reading was found "10.45", which indicated that the solution was basic in nature. The Temperature of the solution was found "25^0 C [3, 10, and 19]. The extraction of metals was made by following Korean standard method [3,10,17].For Fe extraction, first fined grained (150 μm) sample ashes of medical waste were taken and made it oven dry. Then weighted and 5gm was taken.50 ml aqua regia (1:3 of (HNO3) & (HCl)) were mixed with 5 gm sample. After mixing properly this mixer was kept for 24 hours. After 24hours the mixer was digested into the heat Menthol .Then it was filtered. This can be diluted if required. After that, the sample was ready for detection. Before analyzing, the filtrates were kept at 4˚C. For Cu, Cd, Cr & Pd the fined grained (150 μm) sample ashes of medical waste were mixed with a 1:5 ratio of ash to 0.1 N HCl solution .Then the sample were shaken and then filtrated. This can be diluted if required. For detection two machines were used: AAS (Atomic Absorption Spectrophotometer) (Model Varian 220) (for Cu, Cd, Cr detection) and UV (Ultra Violet Spectrophotometer) (Model DR 4000) (for Fe, Pd detection) [10, 28].

2.1 Pollution load index, PLI

Tomlinson's pollution load index (PLI) of the samples was calculated using the heavy metal data and metal concentration for the world shale average as the background value [3, 4, and 5]. The PLI of soils can be calculated by obtaining the n^{th} root from the n number of obtained CF for all the metals [3, 14].

$$PLI = \sqrt[n]{CF_1 \times CF_2 \times CF_3 \times \cdots\cdots\cdots \times CF_n}$$

where, n is the number of heavy metals and CF = $C_{metal}/C_{background}$. The proposed categorization of PLI is shown in Table 2 where the values vary from 0 to 10 [3, 20].

Table 2: Categorization of PLI

PLI value	Soil quality
8-10	extremely polluted
6-8	strongly polluted
4-6	significantly polluted
2-4	moderately polluted
0-2	unpolluted to slightly polluted

2.2 Ecological risk index, RI

Ecological risk index (RI) is defined as the summation of the change occurred in metals with respect to background values considering toxicological factor [6, 7]. The mathematical expression of RI can be shown as

$$RI = \sum_{i=1}^{n} \left(T_i \times \frac{C_i}{C_0} \right)$$

where, n is the number of heavy metals, T_i is the toxic-response factor for a given substance, C_i represents metal content in soil and C_0 is the regional background value of heavy metals [3,13] . As the regional background values of measured heavy metals were unavailable, the metal concentrations for the world shale average were chosen as the background value [3, 23]. Three contamination categories are recognized on the basis of the ecological risks] in heavy metals [3,10, 14].

RI	Category
< 300	low to moderate
$300 \leq RI \leq 600$	high (RI_h)
RI > 600	extremely high ecological risks (RI_e)

2.3 Enrichment Factor

Enrichment factor (EF) of an element in the studied samples was based on the standardization of a measured element against a reference element. The most commonly used reference elements are aluminum (Al), iron (Fe), K and so on [3, 22]. The EF is expressed below as

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$$EF = \frac{(Cx/Fe)_{soil}}{(Cx/Fe)_{background}}$$

where $(C_x/Fe)_{soil}$ is the metal to Fe ratio in the samples of interest, and $(C_x/Fe)_{background}$ is the natural background value of the metal to Fe ratio. In this study, Admittedly, as Fe and heavy metal background values for the study area are not available, the average continental shale metal values have been adopted [3,23]. There is no accepted pollution ranking system or categorization of degree of pollution on the enrichment ratio and/factor methodology [3, 15]. The proposed EF classes along with the sediment quality at various values are shown in Table 3 [3, 10].

Table 3: Categorization of EF

EF value	EF class	Level of enrichment
> 40	6	extremely high enrichment [a]
20-40	5	very high enrichment [a]
5-20	4	significant enrichment [a]
2-5	3	moderate enrichment [a]
1.5-2	2	minimal enrichment [a, b]
0.5-1.5	1	enrichment entirely from crustal materials [b]
< 0.5	0	enrichment from point and non-point sources (E_p) [b]

[a] [22]
[b] [23]

2.4 Geo Accumulation Index

The geo accumulation index (I_{geo}) method was used to calculate the metal contamination levels [16, 25].

$$I_{geo} = \log_2\left(\frac{C_x}{1.5B_x}\right)$$

Where, C_x represents the measured concentration of the element x and B_x is the geochemical background value of the element in fossil argillaceous sediment (average shale). The constant 1.5 is introduced to minimize the effect of possible variations in the background values which may be attributed to litho logic variations in the sediments [25, 27]. The classification is given, as shown in Table 4, for geo accumulation index [25, 26].

Table 4: Categorization of I_{geo}

I_{geo} value	I_{geo} class	Designation of soil quality
> 5	6	extremely contaminated
4-5	5	strongly to extremely contaminated
3-4	4	strongly contaminated
2-3	3	moderately to strongly contaminated
1-2	2	moderately contaminated
0-1	1	uncontaminated to moderately contaminated
0	0	Uncontaminated

3. RESULT AND DISCUSSION

3.1 pH VALUE

The pH of MWBA was in the range of 8.65-9.68 The minimum and maximum values of pH were found for s-1 and s-2 respectively. The average value of pH for all six samples was found 9.26. The individual and
average, all pH values indicate that the samples were alkaline in nature [21].

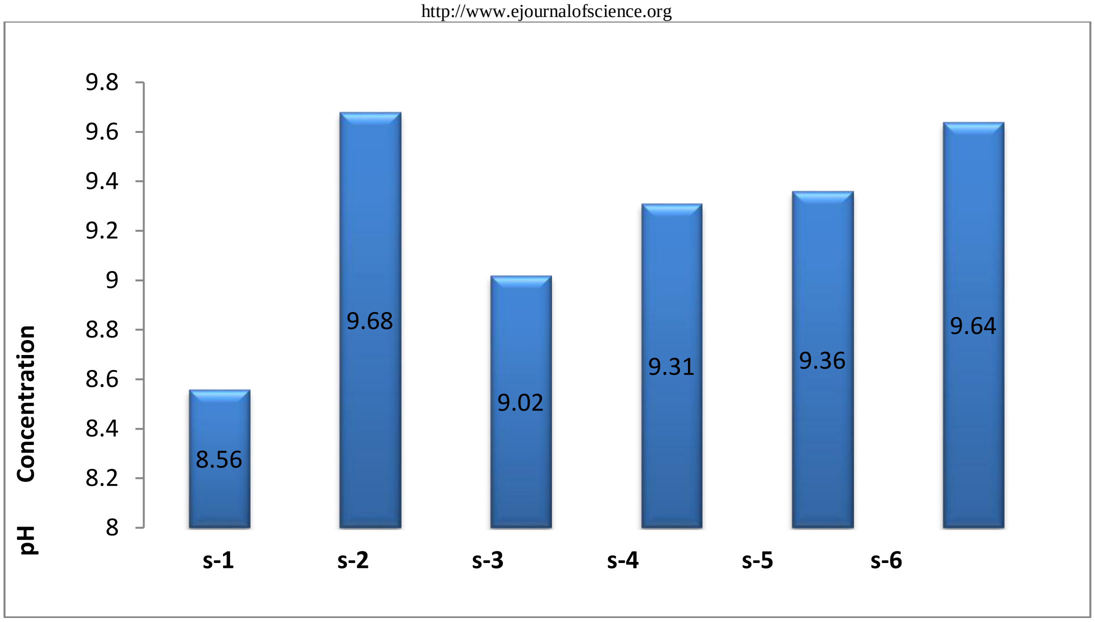

Fig 6: Concentration of pH

4. METAL CONCENTRATION

In this study it was found that the MW bottom ash was enriched with various metallic elements. There were large amount of heavy metals such as Fe, Pb, Cr, Cd, and Cu. Among the priority pollutants Cu (150-254mg kg^{-1}), Cr (17-25 mg kg^{-1}), and Pb (101-160 mg kg^{-1}) exceed the tolerable (SCS & SQG) level of concentration [1, 2]. Concentration of Cd (0.17-1.12 mg kg^{-1}) is below the tolerable level, the reason is, and its compounds are generally easily volatile and thus, may have ended up in the fly ash [8]. Cr concentration exceeds tolerable limit (4-10 mg kg^{-1}) of SCS while it is in the range of unpolluted (<25) to moderately polluted (25-75) limit of SQG [1-2]. Compared to values reported in other literature for medical waste incinerator ashes [8], it is found that Fe concentrations in this study are lower. The possible reason is different compositions of raw MW. In this study MW bottom ash contains higher amounts of Cu (150-254 mg kg^{-1}), and Pb (101-160 mg kg^{-1}). These elements are commonly used in medical facilities [8]. Here logarithmic scale is used to express metal concentration to avoid high fluctuation in concentration of Cr, Pb, and Cu compared to Fe.

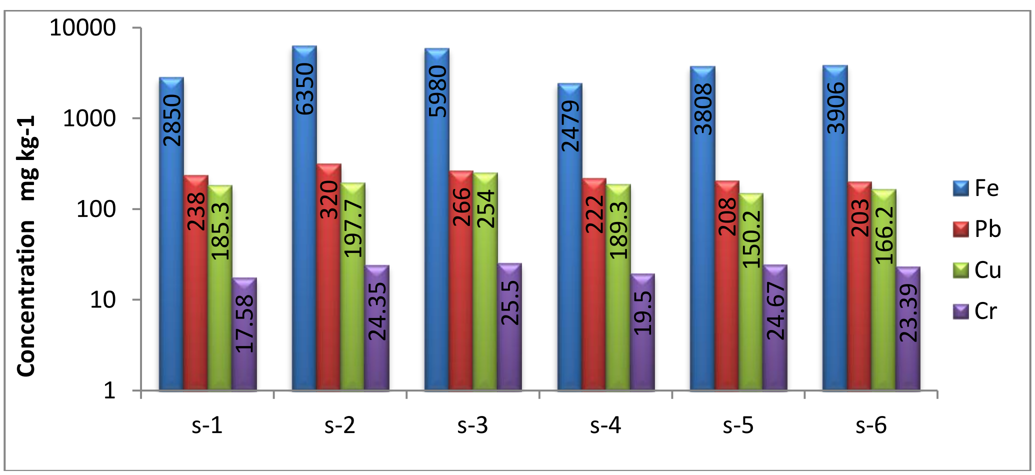

Fig 7: Heavy Metal Concentration mg kg^{-1}

Cd concentration is expressed individually for avoiding negative values in logarithmic scale.

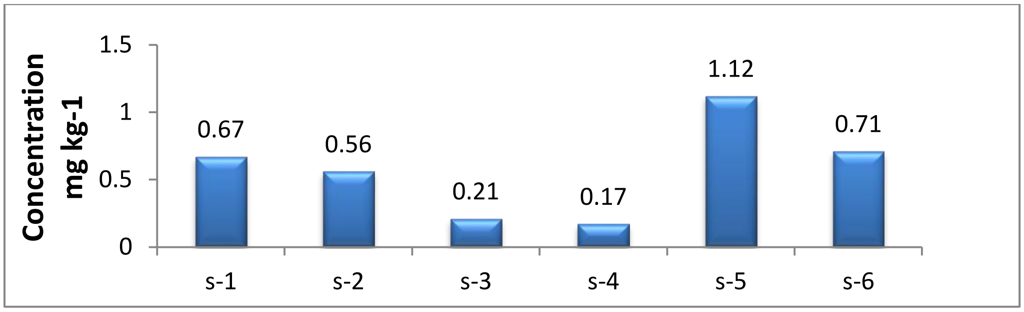

Fig 8: Cd Concentration mg kg^{-1}

5. CORRELATION ANALYSIS

Here a metal to metal correlation was established by using SPSS Statics 17.0. There was no significant correlation observed in changes of Cd, with Cu, Pb and Fe. But Cd showed positive correlation with Cr. Moreover, Cu, Cr, Pb, and Fe exhibited positive correlation to each other, while Fe indicated a significant positive correlation with Cu, Cr and Pb.

Table 7: Metal to Metal correlation

	Cu	Cd	Cr	Pb	Fe
Cu	1				
Cd	-0.75	1			
Cr	0.22	0.16	1		
Pb	0.57	-0.34	0.27	1	
Fe	0.56	-0.12	0.78	0.78	1

6. POLLUTION LOAD ASSESSMENT

The pollution load values varied from 1.44 to 2.27 for ash samples. High pollution load values (2.02 to 2.27) were found for sample 1, 2, 5 and 6, which indicate that, samples were moderately polluted and may cause contamination if disposed to the soil. Again relatively low pollution load values (1.44 to 1.82) were found for sample 4 and 3, respectably which suggest that, samples were slightly polluted and may cause slight contamination if disposed to soil [3, 20] .

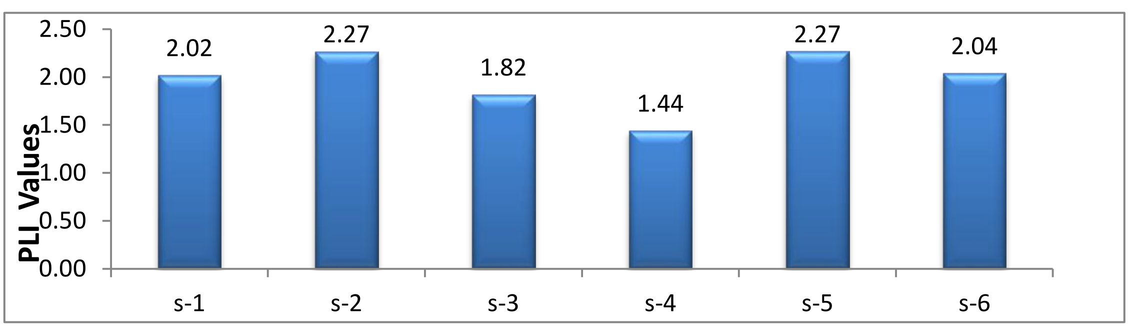

Fig 9: Plots of PLI Value

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7. ECOLOGICAL ASSESSMENT

The graphical presentation of Potential ecological risk indices (RI) is shown below. The highest RI was found for sample-5 (210) and the lowest was found for sample-4 (74).As RI of heavy metals in ash samples were lower than 300, it suggest that ash samples exhibited low and moderate ecological risk of heavy metals[3,10,14].

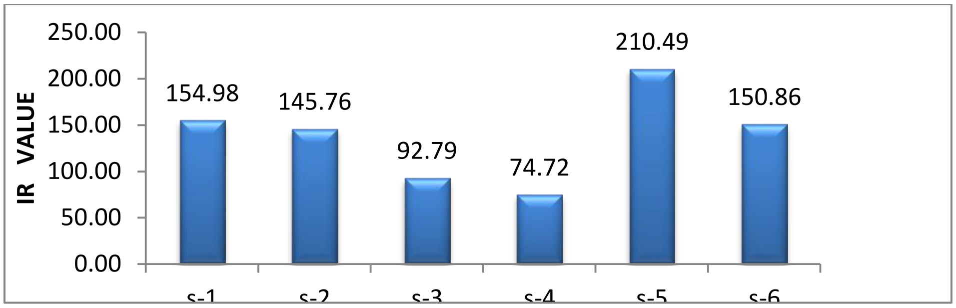

Fig 10: Plots of RI values

8. METAL ENRICHMENT

The values of EF for ash samples with remarks are shown in the table below. The value of EF over 40 was found for Pb, Cu and Cd accordingly as 100%, 80% and 50% of ash samples. These metals possess EF class 6, with remark extremely high enrichment of heavy metal. Cr showed highest EF (4.08) for sample-4 which indicates moderate enrichment [3]. Rests of Cr enrichment were with remark of minimal enrichment to moderate enrichment. 50% of Cd showed extremely high enrichment while other 50% showed moderate enrichment to significant enrichment [3].

Table 8: Values of EF

SAMPLE	EF				CLASS	REMARK
	Cu	Cd	Cr	Pb		
S-1	67.47	58.04	3.20	97.50	6	Extremely High Enrichment
S-2	32.31	20.41	1.99	58.83	6	Extremely High Enrichment
S-3	44.08	8.00	2.21	51.93	6	Extremely High Enrichment
S-4	79.25	16.01	4.08	104.55	6	Extremely High Enrichment
S-5	40.93	68.37	3.36	63.77	6	Extremely High Enrichment
S-6	45.01	42.44	3.11	60.68	6	Extremely High Enrichment
AVERAGE	51.51	35.55	2.99	72.88	6	Extremely High Enrichment

9. GEOACCUMULATED RISK ASSESSMENT

The values of geoaccumulated risk (I_{geo}) assessment are shown in the table below indicating moderately contaminated to moderately to strongly contaminated [3] remarks. In ash samples the value of I_{geo} for sample 1, 4, 5 and 6 was found in class 2, with quality remark moderately contaminated. For sample 2 and 3 I_{geo} was found in class 3 with moderately to strongly contaminated remark. Among all the metal I_{geo}, Pb showed higher values and the highest I_{geo} was 2.42 for sample-2. The I_{geo} for Cr was found in the class 0 with uncontaminated remark. The average I_{geo} for Cu and Cd was found in class 2 and 1 with remark moderately contaminated and uncontaminated to moderately contaminate respectively.

Table 9: Values of I_{geo}

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SAMPLE	I_{geo}				CLASS	REMARKS
	Cu	Cd	Cr	Pb		
S-1	1.46	1.21	-2.94	1.99	2	Moderately Contaminated
S-2	1.55	0.89	-2.47	2.42	3	Moderately to Strongly Contaminated
S-3	1.91	-0.55	-2.40	2.15	3	Moderately to Strongly Contaminated
S-4	1.49	-0.82	-2.79	1.89	2	Moderately Contaminated
S-5	1.15	1.89	-2.45	1.79	2	Moderately Contaminated
S-6	1.30	1.24	-2.53	1.76	2	Moderately Contaminated
AVERAGE	1.48	0.64	-2.60	2.00	2	Moderately Contaminated

10. CONCLUSION

In terms of heavy metal contamination bottom ash is generally considered to be safer than fly ash. However, the study results indicate that MW bottom ash contains high levels of heavy metals. In this study, high concentrations of metallic elements, such as Fe, Pb, Cr, Cd and Cu were determined. Thus, this type of waste ash may cause serious environmental problems if not properly managed.

REFERENCE

[1] Min-yo Lee, Sang-il Choe, Jae-yong Lee, Kang-kun Lee and Jae-wo Park. Soil and Groundwater Environment (Tho-yang Jihasu Hwan-gyeong), Donghwa Publication Co. Ltd., Seoul, Korea 2006, p. 224.

[2] Xu-Chen Wang, Huan Feng and Hai-Qing Ma (2007). Assessment of metal contamination in surface sediments of Jiaozhou bay, Qingdao, China. Clean, 35 (1), pp. 62 – 70.

[3] M. I. Kabir, H. Lee, G. Kim and T. Jun, Monitoring and assessing heavy metals in topsoils as potential diffuse pollutants in the Pyeongchang River Basin, Korea. IWA Publishing 2010, Water Science & Technology—WST. pp 3156-3166.

[4] Tomlinson, D. L., Wilson, J. G., Harris, C. R. and Jeffney, D. W. (1980). Problems in the assessment of heavy metals levels in estuaries and the formation of pollution index. Helgol. Wiss. Meeresunters, 33, p. 566.

[5] Priju, C. P. and Narayana, A. C. (2007). Heavy and trace metals in Vembanad lake sediments. Int. J. Environ. Res., 1(4), pp. 280–289.

[6] L. Hakanson (1980). An ecological risk index for aquatic pollution control: a sedimentological Approach. Water Research, 14, pp. 975–1001.

[7] Zhifeng Yang, YingWang, Zhenyao Shen, Junfeng Niu and Zhenwu Tang (2009). Distribution and speciation of heavy metals in sediments from the mainstream, tributaries, and lakes of the Yangtze River catchment of Wuhan, China. Journal of Hazardous Materials, 166(2 – 3), 1186 – 1194.

[8] Lijuan Zhao,Fu-Shen Zhang ,Mengjun Chen, Zhengang Liu, Da Bo Jianzhi Wu .Typical pollutants in bottom ashes from a typical medical waste incinerator Materials Journal of Hazardous Materials. 173 (2010) 181–185

[9] Miss Patcharin Racho. a study of heavy metal in bottom ash from medical waste incinerator in Nakhonratchasima Municipalty. M.Sc. Engineering Thesis. Department of Environmental Engineering. Suranaree University of Technology (2002).

[10] M.T. Shams, T. purkayastha (2011). Heavy metal assessment of incinerated medical waste. B. Sc. Engineering thesis, Department of Civil and Environmental Engineering, Shahjalal University of Science & Technology, Sylhet, Bangladesh.

[11] Prüss, A., Giroult, E. and Rushbrook, P. (1999). Safe Management of Wastes from Health Care Activities. Geneva: World Health Organization.

[12] Hasselriis, F. and Constantine, L. (1992). Characterization of Today's Medical Waste. In Green, A. E. S. (Ed). Medical Waste Incineration and Pollution

Prevention (pp 37-51). New York: Van Nostrand Reihold.

[13] Zhifeng Yang, YingWang, Zhenyao Shen, Junfeng Niu and Zhenwu Tang (2009). Distribution and speciation of heavy metals in sediments from the mainstream, tributaries, and lakes of the Yangtze River catchment of Wuhan, China. Journal of Hazardous Materials, In Press.

[14] L. Hakanson (1980). An ecological risk index for aquatic pollution control: a sedimentological Approach. Water Research, 14, pp. 975–1001.

[15] Xinwei Lu, Lijun Wang, Kai Lei, Jing Huang and Yuxiang Zhai (2009). Contamination assessment of copper, lead, zinc, manganese and nickel in street dust of Baoji, NW China. Journal of Hazardous Materials, 161, pp. 1058–1062.

[16] Müller, G. (1969). Index of geo accumulation in the sediments of the Rhine River. Geojournal, 2, pp. 108–118.

[17] Myung Chae Jung (2001). Heavy metal contamination of soils and waters in and around the Imcheon Au-Ag mine, Korea. Applied Geochemistry, 16 (11–12), pp. 1369–1375.

[18] Liu Xiaohai, Gao Yuntao, Sardar Khan, Duan Gang, Chen Aikui, Ling Li , Zhao Lei, Liu Zhonghan and Wu Xuecan (2008). Accumulation of Pb, Cu, and Zn in native plants growing on contaminated sites and their potential accumulation capacity in Heqing, Yunnan. Journal of Environmental Sciences, 20, pp. 1469–1474.

[19] Hosik Lee, Md. Imran Kabir, Phil Sang Kwon, Jong Myeong Kim, Jong Gyu Kim, Seung Hun Hyun, Yeon Taek Rim, Myoung Soon Bae, Eul Ryul Ryu and Myung Sook Jung (2009). Contamination assessment of abandoned mines by integrated pollution index in the Han River watershed. The Open Environmental Pollution & Toxicology Journal, 1, pp. 27–33.

[20] Sarva M. Praveena, Miroslav Radojevic and Mohd H. Abdullah (2007). The assessment of mangrove sediment quality in Mengkabong lagoon: an index analysis approach. International Journal of Environmental & Science Education, 2(3), pp. 60–68.

[21] D. Kar, P. Sur, S. K. Mandal, T. Saha, R. K. Kole (2008). Assessment of heavy metal pollution in surface water. Int. J. Environ. Sci. Tech., 5 (1), pp.119-124

[22] H. Yongming, D. Peixuan, C. Junji and E.S. Posmentier (2006). Multivariate analysis of heavy metal contamination in urban dusts of Xi'an, Central China, Sci. Total Environ., 355, pp. 176–186.

[23] G. M. S. Abrahim and R. J. Parker (2008). Assessment of heavy metal enrichment factors and the degree of contamination in marine sediments from Tamaki Estuary, Auckland, New Zealand. Environ. Monit. Assess. 136, pp. 227–238.

[24] Wang, X. S. & Qin, Y.(2007) Some characteristics of the distribution of heavy metals in urban topsoil of Xuzhou, China. Environ. Geochem. Health 29, 11 – 19.

[25] Nastja R. Šmuc, P. VrhoVnik, T. Dolenec, T. Serafimovski, G. Tasev & M. Dolenec. (2009) Assessment of the heavy metal contamination in the surficial sediments of Lake Kalimanci (Macedonia): a preliminary study. RMZ – Materials and Geoenvironment, Vol. 56,No. 4, pp. 437–447, 1

[26] Krzysztof Loska, Jan Cebula, Jacek Pelczar, Danuta Wiechuła and Jerzy Kwapuliński (1997). Use of enrichment, and contamination factors together with geo accumulation indexes to evaluate the content of Cd, Cu, and Ni in the Rybnik water reservoir in Poland. Water, Air and Soil Pollution. 93(1–4), pp. 347–365.

[27] Ghrefat, H., & Yusuf, N. (2006): Asses-sing Mn, Fe, Cu, Zn, and Cd pollu-tion in bottom sediments of Wadi Al-Arab Dam, Jordan. Chemo-sphere; 65, 2114–2121.

[28] S. Sushil & V.S. Batra (2006).Analysis of fly ash heavy metal content and disposal in three thermal power plants in India. Fuel, 85 (17-18), pp 2676-2679.

[29] Peter, M. (1988). New Study Shows Incinerator Ash More Dangerous Than We Realized [Online].Available: http://www.rachel.org/bulletin/bulletin.cfm?Issue_ID=1053.