Heavy metal residue in the landfill area of Tan Deaw sub-district in Saraburi and in adjacent areas

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ABSTRACT

Thailand Institute of Scientific and Technological Research (TISTR) monitors the number of heavy metal residues in soil, surface water, and plants in landfill areas of Tan Daew sub-district, Kaeng Khoi district, Saraburi province for every 3 months from February 2018 to February 2019. The highest levels of heavy metal residues in the soil are found including manganese, lead, and arsenic, averagely at 1,083.00, 22.82 and 4.45 milligrams per kilogram, respectively, which are not exceeding the soil quality standards for living and agriculture except in February and November 2018, where the detection of manganese and arsenic exceed the standard criteria. For heavy metals in the water, a total of 6 elements are found with the value of that are not exceeding the surface water quality standard of type 3. In addition, manganese accumulation is detected in giant Mimosa Pudica plant in the landfill area either in leaves and stems at the amount of 0.14 and 0.05 times the amount of soil residue. And when analyzing the amount of heavy metal residue in soil and water in public areas that is approximately 300 meters away from the landfill area, the result indicates no heavy metal residue found to be exceeding the standard criteria except in February and November 2018 in which arsenic residue in the soil is found to exceed the standard criteria. Moreover, manganese accumulation is detected in morning glory which is 1.2 times more than in soil accumulation. In the area of tap water source production at a distance of about 630 meters, no heavy metal content in the surface of water is found to exceed the standard criteria throughout the period of monitoring. It can be said that the results of this study will be one of the key data in the treatment of harmful residues in the environment including the application of plants to further absorbing heavy metals.

Keywords: Heavy Metal, Landfill Area, Phytostabilization

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Introduction

Current soil and water pollution problems are caused by the accumulation of organic and inorganic compounds including heavy metals in large quantities. Since heavy metals cannot be decomposed by natural processes. Therefore, some are accumulated in the soil, sediment, water, aquatic animals and plants. Heavy metals reported to be found in water and sediment contamination are arsenic (As), iron (Fe), mercury (Hg), lead (Pb), magnesium (Mg), manganese(Mn), molybdenum (Mo), nickel (Ni) and zinc (Zn) (Keepax et al., 2011). Once accumulated in the environment, they will be transmitted along the food chain and accumulated in living things causing harm or hazard to the body in many ways such as causing cancer, destruction of the spine system causing high blood pressure in inhibiting enzyme activity and causing DNA abnormalities (Manahan, 1992). The source of heavy metals in the environment comes from many sources such as the smelting and metal industries, the use of chromium salts in tanning, fuel combustion, manufacturing of cement and block bricks, the operation of vehicles, which is the main source of distribution of lead in the atmosphere. And most importantly, leakage into the landfill area which will affect the soil and nearby water resources (Khala,1998). The amount of waste in Thailand in 2018 has approximately 27.8 million tons. Compared with the year of 2017, it is 1.64 percent increased (Pollution Control Department, 2019). Due to the expansion of urban communities and alteration in the lifestyle from an agricultural society to urban society, increasing population, tourism promotion, increasing consumption, all of these lead to an increase in the amount of waste in many areas. According to community waste management data, it is found that the total amount of community waste collected for disposal is 43,173 tons per day. And of this amount, the waste taken to the proper disposal site is only 26,721 tons per day, with the remaining amount of 16,452 tons per day taken to the improper disposal site such as outdoor burning, littering in the puddle or the abandoned area. In addition, it is found that there are 2,468 incorrect waste disposal locations in the local government organization (Pollution Control Department, 2019). From the above information, the residue of solid waste is also a result of a lack of knowledge and understanding of local people in the management of solid waste and hazardous waste and the ignorance in the importance of waste segregation resulting in the contamination of chemicals with waste. Such chemical residues contain heavy metals such as arsenic, mercury, cadmium, and lead. From the data on the survey regarding hazardous waste in the landfill area within 1 kilometer of Phraeksa Sub-district, Samut Prakan province in September 2014, an analysis of water samples reveals that the amount of heavy metal found to be exceeding the standard criteria of underground and surface water which include arsenic and mercury at concentrations of 0.0131 and 0.0063 milligrams per liter respectively (Environmental Research and Training Center, 2014). This is consistent with the study of heavy metal contamination in soil around the dumping area in Greece which reveals that the levels of heavy metal contamination in the soil are higher than the specified standards (Kasassi et al., 2008). Therefore, this research aims to monitor the amount of heavy metal residue in the landfill area of Tan Daew sub-district, Kaeng Khoi district, Saraburi province and in the adjacent areas, in soil, surface water, and in plants

Equipment and methods

Study Area

Samples are collected from 3 study areas including (1) landfill site of Tan Daew Sub-district, Kaeng Khoi District, Saraburi Province (2) public areas and (3) tap water production sources with the distance of 300 and 630 meters away from the landfill site, respectively. The coordinates at all sampling sites (Figure 1 and Table 1) are recorded. Soil and surface water samples are collected every 3 months between February 2018 and February 2019 and samples of plants are collected between August 2018 and February 2019

Sampling

The soil samples are collected by digging about 30 centimeters deep from the soil surface, using the principle of collecting multiple soil samples from different sources representing collecting of such points. Clean the surface of the soil to be free from impurities. Store the soil into a zipper bag and maintain the temp at 4 ± 2°C until analysis. Surface water samples are collected using grab sampling principles. Conduct sampling from multiple points in the same water source mixed to represent water from different

Table 1 Detail and coordinate of sampling sites

Areas	Places	Coordinates		Distance from municipal dumping site (m)
		Latitude	Longitude	
1	Municipal dumping site	14.5531880	101.0265470	-
2	Public area	14.5523410	101.0207850	300
3	Municipal water source	14.5455750	101.0262910	630

Figure 1 Map of sampling sites; 1) Municipal dumping site; 2) Public area; 3) Municipal water source

sources. Then put samples into the brown bottle, tightly closed the lid and maintain the temp at 4 ± 2C until analysis.

Mimosa pigra plants from all 3 study areas and specimen of morning glory plants from public water sources are collected in which the soil and other weeds attached to the plants must be eliminated. Bake the sample at 60°C to dry for approximately 2-3 days. Grind by using the cutting mill to 1 millimeter diameter before sending it to analyze.

Analysis for Heavy Metal Content

Analyze the heavy metal content in the soil, surface water and plant samples using the Inductively Coupled Plasma-Mass Spectrometry / Optical Emission Spectrometry (ICP-MS / OES), conducted by the Central Laboratory (Thailand) Company Limited (Table 2)

Results and Discussion

Residue of heavy metals in soil samples

From the analysis of heavy metal residues in all 3 sources of the soil sample, it is found that throughout the monitoring period in the landfill area (point 1), the amount of heavy metal residue is higher than the neighboring areas (points 2 and 3). The soil samples from 3 sources have the highest residual heavy metals, namely manganese, lead and arsenic with the average amount of 1,083.00, 22.82 and 4.45 milligrams per kilogram respectively. While the soil samples collected in February and November 2018 is found to contain arsenic levels exceeding the soil quality standard for living and agriculture (2004) approximately 1.1-3.2 times. In addition, the soil samples collected from the landfill site in November 2018 contain more than 1.1 times the amount of manganese residue (Table 3). Such heavy metal residue may come from leachate leaks or residues in the collection of original soil in the said area. This is consistent with U-Tapan et al. (2013) reporting that landfill sites contain some heavy metals in the soil, such as arsenic, zinc in the level exceeding soil quality standards.

The amount of residue of heavy metals in surface water samples

Throughout the period of monitoring of the number of heavy metal residues in surface water samples, which are natural water sources, during February 2018 and February 2019. The average heavy metal residue is found in all 3 sources while the level does not exceed the standard criteria of surface water quality standard type 3 (2004) accumulated in the plants around that area.

Table 2 List of heavy metals analysis

Samples	Heavy metals
Soil	Arsenic (As), Manganese (Mn), Cadmium (Cd), Lead (Pb), Mercury (Hg)
Surface water	Hexavalent chromium (Cr^{+6})
Plants	Arsenic (As), Manganese (Mn), Cadmium (Cd), Lead (Pb), Mercury (Hg)

Table 3 Residue heavy metals in soil

Areas	Residue heavy metals in soil (mg/kg)					
	As	Mn	Cd	Pb	Hg	Cr^{+6}
Municipal dumping site	0.17 - 12.47	439.00 – 1,974.50	0.07 - 0.15	14.72 - 40.85	0.02 - 0.04	0.54 – 0.89
Public area	0.19 - 7.91	842.01 – 1,264.40	0.04 - 0.09	8.00 - 20.10	0.00 - 0.01	0.36 – 0.91
Municipal water source	0.08 - 8.13	360.50 - 707.48	0.03 - 0.13	9.57 - 18.15	0.00 - 0.02	0.34 – 0.65
Standard of soil quality	≤3.9	≤1,800	≤37	≤400	≤ 23	≤ 300

Table 4 Residue heavy metals in surface water

Areas	Residue heavy metals in surface water (mg/L)					
	As	Mn	Cd	Pb	Hg	Cr^{+6}
Municipal dumping site	0.0020 – 0.0035	0.0423 – 0.3964	Not detected	0.0010 – 0.0011	0.0003 – 0.0006	0.0046 – 0.0504
Public area	0.0020 – 0.0036	0.0213 – 0.8589		0.0000 – 0.0010	0.0002 – 0.0006	0.0062 – 0.0337
Municipal water source	0.0022 – 0.0030	0.0447 – 0.2275		0.0002 – 0.0060	0.0003 – 0.0007	0.0158 – 0.0365
Standard of surface water quality	≤0.01	≤1.0	≤0.05	≤ 0.05	≤0.002	≤0.05

The content of heavy metal residues in plant samples

From the analysis of the heavy metal content in all 3 giant mimosa trees collected between August 2018 and February 2019, manganese is the element with the highest accumulation level either in leaves and stems collected from the pond in the landfill area with the amount of 281.63 and 73.99 milligrams per kilogram respectively or equivalent to 0.14 and 0.05 times the amount of residue in the soil while morning glory plants from public water sources (point 2) indicate an average accumulation of manganese and arsenic at 1,249.29 and 3.04 milligrams per kilogram, respectively, which is 10 times 22 times higher than those accumulated in the leaves of giant Mimosa pigra and about 5-8 times higher than those in the giant Mimosa pudica trunks. This is maybe due to the results that morning glory plant is a succulent plant that

Table 5 Residue heavy metals in plants

Plants		Areas	Residue heavy metals in plants (mg/kg)				
			As	Mn	Cd	Pb	Hg
Mimosa pigra	Leaves	Municipal dumping site	0.06 - 0.20	96.85 - 281.63	0.01 - 0.03	0.24 - 0.61	0.02 - 0.03
		Public area	0.05 - 0.06	51.52 - 112.34	0.01 - 0.02	0.07 - 0.14	0.01 - 0.07
		Municipal water source	0.03 - 0.12	18.34 - 136.15	0.01 - 0.03	0.22 - 0.30	0.00 - 0.01
	Stems	Municipal dumping site	0.04 - 0.10	36.05 - 73.99	0.01 - 0.06	0.07 - 0.14	0.00 - 0.03
		Public area	0.05 - 0.20	142.58 - 175.46	0.00 - 0.01	0.03 - 5.75	0.01 - 0.37
		Municipal water source	0.02 - 0.06	102.27 - 319.42	0.00 - 0.01	0.18 - 0.34	0.00 - 0.01
Ipomoea aquatica		Public area	1.22 – 5.02	383.74 – 2820.26	0.02 – 0.06	0.62 – 4.03	0.01 – 0.56

has a structure as different from giant Mimosa pigra, which is a perennial plant. In addition, manganese accumulation in morning glory has a level of 1.2 times higher than accumulation in soil (Table 5). This is consistent with Ashraf et al. (2011) reporting that the Mimosa pigra plant can accumulate heavy metals (arsenic, copper, lead and zinc) up to 700 milligrams per kilogram. For morning glory, it can accumulate heavy metals (manganese and cadmium) too (Guan et al., 2017).

Conclusion

There are the findings of arsenic and manganese in soil exceeding the soil quality standards in the landfill area of Tan Deaw Sub-district, Kaeng Khoi District, Saraburi Province since the soil is a solid particle that can freeze heavy metals from landfills better than liquid-phase water. In addition, the more accumulation of arsenic and manganese in the morning glory plant is detected than in the giant mimosa pigra, in which the data obtained from this study will be an important basis useful for further development for the treatment of dangerous residues in the environment including the application of plants to further absorb heavy metals

Acknowledgment

We thank you to the Thailand Institute of Scientific and Technological Research (TISTR) for funding the research project, assessing the potential for degradation of harmful substances from the environmental waste ponds of microbial communities in the area for the fiscal year 2017-2019.

And we would like to thank Tan Daew Sub-district Administrative Organization, Kaeng Khoi District, Saraburi Province in providing courtesy of the landfill sites and adjacent area as a sample collection area for this study

Reference

Ashraf, M.A., M.J. Maahand and I. Yusoff. 2011. Heavy metals accumulation in plants growing in ex tin mining catchment. Int. J. Environ. Sci. Tech. 8 (2): 401-416.

Environmental Research and Training Center. 2014. Affected by landfill fire, Phraekkasa subdistrict, Samutprakan Province. Department of Environmental Quality, Ministry of Natural Resources and Environment. (in Thai)

Guan, B.T.H., M.Y. Ferdaus, N. Halimoon and Y. Christina Seok Yien. 2017. Uptake of Mn and Cd by wild water spinach and their bioaccumulation and translocation factors. Environment Asia. 10 (1): 45-51.

Kasassi A., P. Rakimbei, A. Karagiannidis, et al. 2008. Soil contamination by heavy metals: Measurements from a closed unlined landfill. Bioresour. Technol. 99 (18): 8578-8584.

Keepax, R. E., L.N. Moyes, F.R. Livens. 2011. Speciation of heavy metals and radioisotopes. Env. and Ecol. Chem. 2: 165-199.

Khala, P. 1998. Potential of Petchaburi river for heavy metal absorption in overflow wastewater from Phetchaburi municipal wastewater treatment system. MS Thesis, Kasetsart University, Bangkok. (in Thai)

Manahan, S. E. 1992. Toxicological chemistry. 2nd ed. USA, Lewis Publishers, INC.

Pollution Control Department. 2019. Thailand pollution report. Ministry of Natural Resources and Environment. (in Thai)

Utapan, S., N. Laemun, P. Paopongsawan, et al. 2013. A study of environmental contamination from hazardous waste and the community management. Disease Control Journal. 39 (3): 258-265. (in Thai)