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Possibility of Heavy Metals Contaminated Solid Waste from Municipal Waste Disposal Sites in Pangkor Island Perak State, Malaysia

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Abstract: Inappropriate waste handling and disposal causes many problems that are acute and widespread. One of these is the decomposition of waste into constituent chemicals which contaminate air and water systems. This study presents investigation of possibility of heavy metals contaminated solid waste from municipal waste disposal sites in Pangkor Island. For this purpose, a total of nine MSW samples of food, paper and plastic were collected from the Teluk Cempedak disposal sites in Pangkor Island in 2010 to determine the levels of Cd, Cu Pb and Zn. Heavy metals were digested by method of strong acid based on the EPA SW 846 method 3050 as stated by Kimbrough and analysed using method of Flame Atomic Absorption Spectroscopy (AAS). The results were further compared with permissible limits for Canadian and USEPA compost standards. The highest concentration is Cu (562.9±6.7015 mg kg^{-1}) and this is observed in paper waste while the lowest concentration is Pb (6.60±4.9153 mg kg^{-1}) in plastic waste. Heavy metal concentrations of the wastes were found to be in the following order: Cu>Zn>Cd>Pb. The mean concentration of Cu (229.20±252.56 mg kg^{-1}) is followed by Zn (93.04±60.67 mg kg^{-1}), Cd (16.69±8.1841 mg kg^{-1}) and Pb (13.01±7.961 mg kg^{-1}). The results showed that the concentrations were within the heavy metal limits of the Canadian and USEPA compost standards. Based on the findings the MSW is suitable for composting as concentrations of Cd, Cu, Pb and Zn are within permissible limits for compost.

Key words: Open landfill, heavy metal, solid waste, Island waste management, Pangkor Island, Malaysia

INTRODUCTION

The nature of modern waste streams is unlike the predominant organic waste of the past both in size and complexity. These materials may take years to decompose. Couple with this is the introduction of substances that are harmful or toxic and have become more frequent in MSW. As pointed out by UNEP (2002), prior to the introduction of imported goods and packaging the waste produced from a typical Pacific Island was entirely organic in origin and could be broken down or composted without thought or problem. However in the present day, it contains more and more industrial products and materials, i.e., glass, metals, plastics and hazardous substances (SPREP/UNEP, 1999). These materials have increased to the point where significant problems are being experienced in many of these small islands. The shift in waste stream from simple to complex material flux have been attributed to Western influences, tourism, imported goods and effects of expatriate communities (SPREP/UNEP, 1999). However, Hoo and Sakurai (1996) added that imported goods generate an excessive amount of package waste such that waste minimization measures as recycling of package waste practicable in other parts of the world are not easily applicable in Pacific Island Countries. According to these researchers packaging materials represent a significant amount of the municipal waste stream and they have a relatively short use life as it soon becomes waste and must be treated or disposed off. These materials are used basically to contain, handle and to ensure hygiene of goods but are increasing and becoming difficult to manage.

Many common household products contain hazardous chemicals, invariably small quantities of these chemicals can accumulate over time to reach dangerous levels and contaminate the air, water and soil. Others can have a more immediate and devastating effect such as poisoning. Once poorly treated materials are discharged into the environment, they may pose a serious threat to living organisms. According to SPREP/UNEP (1999) in small islands various incidents involving toxins from industrial waste, effluent from abattoirs or food processing plants, biocides and polluted effluent from sawmills and timber processing areas have been reported.

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In many cities of small island developing states the lack of adequate treatment of solid wastes including industrial wastes is been observed as one of the major problems to be solved.

Heavy metals could be referred to metallic chemical element that has a relatively high density and is toxic or poisonous at low concentrations. Examples includes: Mercury (Hg), Cadmium (Cd), Copper (Cu) Arsenic (As), Zinc (Zn), Chromium (Cr), Thallium (Tl) and Lead (Pb). They cannot be degraded or destroyed, they may end up in solid waste during all life cycle phases of the products and the main part of the heavy metals will still be present when the discarded products are disposed off. Heavy metals are notable for their wide environmental dispersion, their tendency to accumulate in selected tissues of the human body and their overall potential to be toxic even at relatively minor levels of exposure as trace elements, some heavy metals (e.g., copper, selenium and zinc) are essential to maintain the metabolism of the human body. However, at higher concentrations they can lead to poisoning. While some other metals are xenobiotics, i.e., they have no useful role in human physiology (and most other living organisms) (Howard, 2002). To a small extent they enter the bodies via food, drinking water and air. People working in or living near an industrial site which utilizes these metals and their compounds increases ones risk of exposure as does living near a site where these metals have been improperly disposed (Martin and Griswold, 2009). Agriculture in these areas faces major problems due to heavy metal transfer into crops and subsequently into the food chain.

For example in humans, long-term exposure of cadmium is associated with renal disfunction and high exposure can lead to obstructive lung disease and has been linked to lung cancer. Cadmium may also produce bone defects (osteomalacia and osteoporosis) in humans and animals. Its toxicity is linked with reproduction problem because it affects sperm and reduces birth weight. It is a potential carcinogen and seems to be a causal factor in cardiovascular diseases and hypertension. When cadmium is present in soils it can be extremely dangerous as the uptake through food will increase. Soils that are acidified enhance the cadmium uptake by plants. This is a potential danger to the animals that are dependent upon the plants for survival. Cadmium can accumulate in their bodies, especially when they eat multiple plants. Cows may have large amounts of cadmium in their kidneys due to these (Lenntech, 1998). The same researcher pointed out that earthworms and other essential soil organisms are extremely susceptive to cadmium poisoning. They can die at very low concentrations and this has consequences for the soil structure and when cadmium concentrations in soils are high they can influence soil processes of microorganism and threat the whole soil ecosystem. In aquatic ecosystems cadmium can bioaccumulate in mussels, oysters, shrimps, lobsters and fish. The susceptibility to cadmium can vary greatly between aquatic organisms. Salt-water organisms are known to be more resistant to cadmium poisoning than freshwater organisms. Animals eating or drinking cadmium sometimes get high blood-pressures, liver disease and nerve or brain damage (Lenntech, 1998).

Copper does not break down in the environment and therefore a threat to the environment because when copper ends up in soil it strongly attaches to organic matter and minerals. As a result it does not travel very far after release and it hardly ever enters groundwater. In surface water copper can travel great distances, either suspended on sludge particles or as free ions. On copper-rich soils only a limited number of plants have a chance of survival and can seriously influence the proceedings of certain farmlands, depending upon the acidity of the soil as it negatively influences the activity of microorganisms and earthworms (Lenntech, 1998).

In the environment, lead is known to be toxic to plants, animals and microorganisms. In humans it can cause high blood levels can inhibit haem synthesis, cause irritation, mental retardation, brain damage and produce tumour. It accumulates in the bodies of water and soil organisms. These will experience health effects from lead poisoning. Health effects on shellfish can take place even when only very small concentrations of lead are present. Body functions of phytoplankton can be disturbed when lead interferes. Phytoplankton is an important source of oxygen in seas and many larger sea-animals eat it (Lenntech, 1998).

Some fish can accumulate zinc in their bodies when they live in zinc-contaminated waterways. When zinc enters the bodies of these fish it is able to bio magnify up the food chain. When the soils of farmland are polluted with zinc, animals will absorb concentrations that are damaging to their health (Lenntech, 1998). According to Lenntech, zinc cannot only be a threat to cattle but also to plant species. Plants often have a zinc uptake that their systems cannot handle, due to the accumulation of zinc in soils. Animals can also accumulate metals as well by eating plants, fish or drinking water with elevated metal concentrations. These metals are not excreted by the animals rather they accumulate mostly in the organs as well as the skin, hair and bones. Fish accumulate metals from the water they live in as well as from organisms they eat (Howard, 2002).

MATERIALS AND METHODS

Pangkor Island is a charming island located in Perak State. It is just off the coast of North-West Malaysia and about 300 km North from the country's capital, Kuala Lumpur. Pangkor Island is the largest of a group of nine islands across the Manjung Straits opposite Lumut (MBH, 2010). In Perak State the Island is situated in the Mukin of Lumut, district of Manjung in Perak Darul Ridzuan. The island occupies approximately 8 km^2 and can be located on the coordinates latitude: 4°13'0"N, longitude: 100°34'0"E (Ghollasimood *et al*., 2011). The only landfill that officially serves the island is located in Teluk Cempedak disposal site which is located in the North-Eastern part of Pulau Pangkor, Perak Darul Ridzuan formally off the coast of Selat Manjung. This area occupies a total size of 20234 m^2 (5 acres). Figure 1 shows the map Pangkor Island.

The solid waste disposal on Pangkor depends on dumping on sites that has exceeded its capacity. Yachiyo Engineering Co. Ltd. (2004) describes the landfill as a level 1 landfill (landfilled that feature controlled tipping but are without solid waste retaining structures, e.g., bund, cells and are not covered with soil daily). The volume of tipped waste depth progressively increased over the years, resulting in waste mounds up to 9 m depth.

In general the study area is characterized by a hilly terrain. Elevation contours range from about 10-300 m above MSL (Mean Sea Level). According, to the same researcher from the Teluk Cempedak disposal sites, across the main island road lies Bukit Pangkor, a forested hill which is about 371 m above MSL. This area demarcates the highest point in the island. The island has a warm and humid climate with sunshine all year round and is typical for Pulau Pangkor. Local and region climate is defined by two distinct monsoon seasons with two shorter inter monsoon periods. The temperature in the area is consistent throughout the year with an annual mean daily temperature ranging from a minimum of 23.2°C to a maximum of 32.1°C. The average monthly variations do not exceed 1.3°C. Ghollasimood *et al*. (2011) explained further that the highest mean temperature is in February to May (average 27.65°C) and the minimum occurs during September to December (average 26.8°C). Relative humidity is considered high and fairly stable over the year with the minimum to maximum 24 h mean relative humidity ranging from 83.3-87.2%. Two distinct rainy seasons are observed throughout the year usually occurring in April and in October while dry seasons are observed from June to August and early in the year. February and March are the driest month (Ghollasimood *et al*., 2011). Weathering process of the surrounding granite rocks, yield to granite soil (mainly of completely weathering grade (V) to highly weathered grade (IV) classification). Ghollasimood *et al*. (2011) described the texture of topsoil as mainly sandy loam soil.

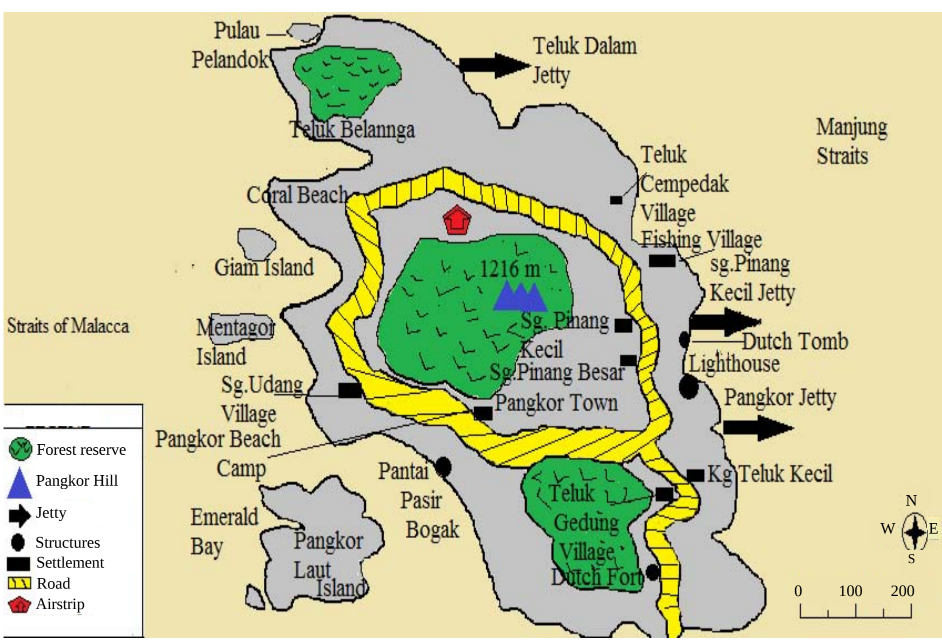

Fig. 1: Map of Pangkor Island

Research methods: To achieve the research objectives, the research had been dependent on data collection. Datas were collected from both secondary and primary sources. Qualitative approaches were dependent on gathering of secondary data from documents, books, articles, internet sources, various organization and other sources of information from the study area. The primary method of data collection involves a two stage analysis which includes a field investigation and laboratory. However, a preliminary field investigation was also involved. These involved an assessment of the disposal sites and informal contacts with Manjung Municipal Council (Majilis Perbandaran Manjung (MPM)) staffs.

Field investigation: The field investigation was carried out in the month of January 2011 in Pangkor Island in order determine the chemical characteristics (mainly the heavy metal) of a representative number of mixtures of waste. Sample of MSW for this study was obtained in the Teluk Cempedak disposal sites. Field data collection included the following tasks.

The sampling: A total of 24 truck load trips of waste were sampled and 50 kg of waste samples were collected from each truck load. Solid waste samples were collected randomly and segregated everyday for 5 continuous days (Tuesday to Saturday) in the Island. Excess weights were discarded and sample size weighed a minimum of 200 kg. The determination of sample size was carried out according to that recommended by Corbit.

Handling of laboratory samples: The laboratories, samples for heavy metal analysis were collected at the same time during sampling. The laboratory samples consisted of four sub samples: food waste, plastics (film and bags), studies (news paper and cardboard) and yard waste. Each fraction being in the range of 1-2 kg. The waste samples were collected in duplicate in plastic bags and were double bagged and sealed. Holding time before analysis was about 96 h.

Laboratory analysis: The laboratory analyses carried out for determination of heavy metal content of the MSW samples in Palau Pangkor included: Pb, Cd, Zn and Cu by method of Flame Atomic Absorption Spectroscopy (AAS)

Digestion of samples: The digestions of the solid waste samples for heavy metal determination were done by method of strong acid based on the EPA SW 846 Method 3050 as stated by Kimbrough (1989). The procedure is explained: 1.00 g of individual waste samples (dry weight) of food, paper and plastic (sized reduced) were placed in separate 150 mL beakers and digested first with 10 mL of 1:1 nitric acid on a hot block without boiling at 95°C for 15 min in a fumehood. The beakers were covered with watch glass. The samples were removed from the hot block and allowed to cool and then 5 mL of concentrated nitric acid was added into each beaker. At this time brown fumes were generated, indicating oxidation of the sample by nitric acid.

The tubes were placed back in the hot block and the resultant mixture is refluxed for 15 min. This step is repeated until the fumes are given off and the samples no longer changes in appearance. The digestate is then concentrated to 5 mL by allowing the solution to evaporate without boiling on the hot block. About 30% hydrogen peroxide was then continuously added with warming until the effervescence is minimal. The samples were treated with no >10 mL of 30% hydrogen peroxide. Finally, 5 mL of concentrated hydrochloric acid was added and the samples were covered with a watch glass and refluxed for 15 min. The samples were continuously heated while covered until solution reduced to about 5 mL again (without boiling). After cooling the samples at room temperature the digestate were filtered through a filter paper (Whatman No. 41) and was collected and made up to 100 mL in a 100 mL measuring flask. The resultant solutions were sent to Chemistry Department, Universiti Kebangsaan Malaysia (UKM) for determination of Pb, Cd, Zn and Cu by method of AAS.

Calculation of heavy metal concentrations: Standard solutions of 2, 4, 6 and 10 ppm corresponding to Cd, Cu, Pb and Zn concentrations of 100 ppm were prepared for comparison based on absorbance of each solution and was measured. Analyses were then carried out using AAS (Spectrometer AA800, Auto Sampler Model AS-90A). The concentrations of the heavy metal in the solutions as obtained by AAS were in mg/L level.

The values in mg/L level were estimated and found to be in mg/kg level. Analyses were carried out in triplicates. Replicate analysis ensured the reliability of the data. All regents used were of analytical grade including standard stock solutions of known concentrations of different heavy metals. The steps involve in calculating the concentration of heavy metals per kilogram of waste sample are explained. The heavy metals in 1.00 g waste sample have been dissolved (by various reactions) in 100 mL. Taking example of heavy metal Cd then researchers have:

$$A\ (mg/L)\text{-}B\ (mg/L) = X1,\ X2 \text{ and } X3\ (mg/L) \text{ of Cd} \tag{1}$$

Where:

A	=	Sample concentration (as obtained by Atomic Absorption Spectroscopy (AAS))
B	=	Blank correlation
X1, X2 and X3	=	Sample concentration (mg/L) of heavy metals (as calculated)

$$\frac{1.00\text{ g of waste sample contain }\left(\frac{100}{1000}\right)\text{L}}{1\text{ g}\times(X1,\ X2\text{ and }X3)\text{ mg/L of heavy metal Cd}} = \frac{0.1\text{ L}}{1\text{ g}\times(X1,\ X2\text{ and }X3)\text{ mg/L of Cd}} \tag{2}$$

Level of waste sample contain (mg/g)= 0.1 g×(X1, X2 and X3) mg of Cd

$$1\text{ kg of waste samples contains} = 0.1\text{ g}\times(X1,\ X2\text{ and }X3)\text{ mg of Cd}\times1000 \tag{3}$$

Multiplying (X1, X2 and X3) mg/g by 1000 as in Eq. 2 then we have the concentration in mg/kg level of waste samples. The values were averaged and then reported as the mean concentration of heavy metal in each of the analyzed waste component (refer to the example). The overall mean concentration of the heavy metal contents across the entire waste were calculated by summing up the values of all the relevant samples analyzed of individual heavy metal content and the average was taken as the overall mean concentration of heavy metal content in the MSW waste samples irrespective of the waste component it occurred.

RESULTS AND DISCUSSION

Heavy metal content: The heavy metals that were analyzed were Cd, Cu, Pb and Zn which consist of concentration in plastic (Table 1), paper (Table 2) and food (Table 3). Finding showed the highest concentration of heavy metal in waste composition is Cu (562.9 mg kg^{-1}) and this is observed in paper waste (Table 4) while the (Table 5). Table 4-6 shows the mean concentration and the standard deviation of the heavy metals content of lowest concentration is Pb (6.60 mg kg^{-1}) in plastic waste the MSW (plastic, paper and food) from open landfill

Table 1: Heavy metal concentration in plastic waste samples

	Replicate sample 1			Replicate sample 2			Replicate sample 3		
Parameters	A	B	A-B = X1	A	B	A-B = X2	A	B	A-B = X3
Cd	0.130	0.003	0.127	0.276	0.006	0.270	0.083	0.002	0.081
Cu	0.408	0.001	0.407	0.361	0.001	0.360	0.317	0.001	0.316
Pb	0.123	0.001	0.122	0.046	0.000	0.046	0.030	0.000	0.030
Zn	0.794	0.107	0.687	0.826	0.111	0.715	0.822	0.111	0.711

Table 2: Heavy metal concentration in paper waste samples

	Replicate sample 1			Replicate sample 2			Replicate sample 3		
Parameters	A	B	A-B = X1	A	B	A-B = X2	A	B	A-B = X3
Cd	0.183	0.004	0.179	0.215	0.004	0.211	0.054	0.001	0.053
Cu	5.593	0.018	5.575	5.723	0.019	5.704	5.626	0.018	5.608
Pb	0.278	0.001	0.277	0.120	0.001	0.119	0.182	0.001	0.181
Zn	1.964	0.264	1.700	1.989	0.268	1.721	1.996	0.269	1.727

A is sample concentration as obtained by AAS (mg/L); B is blank correlation; X1-X3 is sample concentration (calculated) (mg/L)

Table 3: Heavy metal concentration in food waste samples

	Replicate sample1			Replicate sample 2			Replicate sample 3		
Parameters	A	B	A-B = X1	A	B	A-B = X2	A	B	A-B = X3
Cd	0.220	0.004	0.216	0.095	0.002	0.093	0.278	0.006	0.272
Cu	0.915	0.003	0.912	1.028	0.003	1.025	1.048	0.003	1.045
Pb	0.065	0.000	0.065	0.213	0.001	0.212	0.126	0.001	0.125
Zn	0.431	0.058	0.373	0.434	0.058	0.376	0.421	0.057	0.364

A is sample concentration as obtained by AAS (mg/L); B is blank correlation; X1-X3 is sample concentration (calculated) (mg/L)

Table 4: Mean concentration of heavy metal content in paper waste samples

Parameters	X1	X2	X3	Mean±SD
Cd (mg L^{-1})	0.179	0.211	0.053	0.1477±0.0835
mg kg^{-1}	17.90	21.10	5.300	14.77±8.353000
Cu (mg L^{-1})	5.575	5.704	5.608	5.629±0.06700
mg kg^{-1}	557.5	570.4	560.800	562.9±6.7015000
Pb (mg L^{-1})	0.277	0.119	0.181	0.1923±0.0796
mg kg^{-1}	27.70	11.90	18.100	19.23±7.960740
Zn (mg L^{-1})	1.700	1.721	1.727	1.716±0.01420
mg kg^{-1}	170.0	172.1	172.700	171.6±1.4177000

Table 5: Mean concentration of heavy metal content in plastic waste samples

Parameters	X1	X2	X3	Mean±SD
Cd (mg L^{-1})	0.127	0.270	0.081	0.1593±0.0986
mg kg^{-1}	12.70	27.000	8.100	15.93±9.856100
Cu (mg L^{-1})	0.407	0.360	0.316	0.361±0.04550
mg kg^{-1}	40.70	3.600	31.600	25.30±19.33570
Pb (mg L^{-1})	0.122	0.046	0.030	0.066±0.04920
mg kg^{-1}	12.20	4.600	3.000	6.60±4.915300
Zn (mg L^{-1})	0.687	0.715	0.711	0.7043±0.0151
mg kg^{-1}	68.70	71.500	71.100	70.43±1.514300

Table 6: Mean concentration of heavy metal content in food waste samples

Parameters	X1	X2	X3	Mean±SD
Cd (mg L^{-1})	0.216	0.093	0.272	0.1937±0.0916
mg kg^{-1}	21.600	9.300	27.20	19.3700±9.1566
Cu (mg L^{-1})	0.912	1.025	1.045	0.9904±0.0717
mg kg^{-1}	91.200	102.500	104.5	99.4000±7.1715
Pb (mg L^{-1})	0.065	0.212	0.125	0.1340±0.0739
mg kg^{-1}	6.500	21.200	12.50	13.4000±7.39121
Zn (mg L^{-1})	0.373	0.376	0.364	0.3710±0.0062
mg kg^{-1}	37.300	37.600	36.40	37.1000±0.6245

± denotes Standard Deviation (SD); Number of replicate samples (N) = 3; X1-X3 is sample concentration (calculated) site in Pangkor Island. For example, the concentration in mg/kg level of heavy metal Cd is 0.127 mg L^{-1} (Table 5) in replicate sample 1. This step is repeated in bringing the heavy metal concentrations to mg/kg level in the waste samples.

Example: Equation 3 and 4 is expressed as:

$$A\ (mg/L)\text{-}B\ (mg/L) = X1,\ X2 \text{ and } X3\ (mg/L) \quad (4)$$

$$1 \text{ g of waste sample} = 0.1\times(X1,\ X2 \text{ and } X3) \text{ mg of Cd} \quad (5)$$

Taking example of heavy metal Cd in Appendix F1A, researchers have:

$$0.130\ (mg/L)\text{-}0.003\ (mg/L) = 0.127\ (mg/L)$$

1 g of waste samples contains:

$$\frac{0.1 \text{ L}}{1 \text{ g}\times 0.127 \text{ mg L}^{-1}} = 0.1 \text{ g}\times 0.127 \text{ mg}$$

$$= 0.0127 \text{ mg g}^{-1}$$

$$1 \text{ kg of waste samples} = 0.0127\times 1000$$

$$= 12.70 \text{ mg kg}^{-1}$$

Among the three waste components analysed, paper waste showed the highest concentration of Cu and Zn metal. The content of these metals in paper waste reached 562.9 and 171.6 mg kg^{-1}, respectively. Taking the mean of the overall concentration of the heavy metals contents of all the relevant samples analyzed the result showed that Cd is 16.69 mg kg^{-1}; Cu (229.20 mg kg^{-1}); Pb (13.01 mg kg^{-1}) and Zn (93.04 mg kg^{-1}). In the overall, the values of Cu and Zn were comparatively high compared to the other metals. The mean concentration of Cd (16.69 mg kg^{-1}) and Pb (13.01 mg kg^{-1}) are comparatively less than that obtained for the other metals (Table 7 and 8). Therefore, the order observed for this study for heavy metal concentrations in the waste samples are: Cu>Zn>Cd>Pb. Figure 2 shows the overall mean concentrations of heavy metal content in MSW from Teluk Cempedak disposal sites in Pangkor Island.

It must be emphasized that the figures for the overall mean concentration of heavy metals assume that the chemical composition of any given component is the same regardless of the waste stream it occurs in. However, the component of food, paper and plastic are the main heavy metal sources of MSW in Pangkor Island due to the fact that these three were observed to be the dominant component in the waste stream accounting for 78.09% of the entire waste. Furthermore, the results of the heavy metal content of the current study were further compared with the permissible heavy metals concentration limits for compost, according to the United State Environmental Protection Agency (USEPA) standard and Canadian permissible limits. This is shown in Table 9.

When compared with the USEPA standard for compost, the MSW components from Pangkor Island were all within limits. Applying the Canadian permissible limits the results also shows that all the heavy metal content of the waste in Teluk Cempedak in Pangkor Island

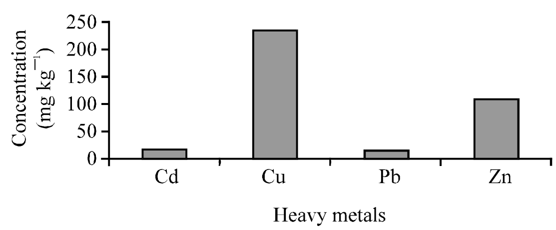

Fig. 2: Overall mean concentrations of heavy metal content in MSW from Teluk Cempedak Disposal sites in Pangkor Island

Table 7: Overall mean concentration of heavy metal content in Msw samples

	Food waste			Paper waste			Plastic waste			
Parameters	X1	X2	X3	X1	X2	X3	X1	X2	X3	Overall Mean±SD
Cd	21.6	9.3	27.20	17.90	21.10	5.3	12.7	27.0	8.1	16.69±8.1841
Cu	91.2	102.5	104.5	557.5	570.4	560.8	40.7	3.6	31.6	229.20±252.56
Pb	6.5	21.2	12.50	27.10	11.90	18.1	12.2	4.6	3.0	13.01±7.9610
Zn	37.3	37.6	36.40	170.0	172.1	172.7	68.7	71.5	71.1	93.04±60.670

Concentration is in mg/kg level; ± denotes Standard Deviation (SD); Number of replicate samples (N) = 9; X1-X3 is sample concentration (m/kg) level

Table 8: Heavy metal content of MSW from Pangkor Island mean values (mg/kg)

Parameters	Food	Paper	Plastic	Overall Mean±SD
Cd	19.37±9.1566	14.77±8.35300	15.93±9.85610	16.69±8.1841
Cu	99.4±.171500	562.9±6.701500	25.30±19.3357	229.20±252.56
Pb	13.4±7.39121	19.23±7.96074	6.60±4.91530	13.01±7.9610
Zn	37.1±0.62450	171.6±1.417700	70.43±1.51430	93.04±60.670

± denotes Standard Deviation (SD); Number of replicate samples (N) = 9

Table 9: Comparison of the heavy metal content of the waste from Pangkor Island and the permissible concentration limits of USEPA and Canadian standard for compost (mg/kg)

Parameters	[a]USEPA compost standards (mg/kg)	Canadian compost standards (mg/kg)	Food	Paper	Plastic	Overall mean
Cd	39.0	20	19.37	14.77	15.93	16.69
Cu	1500.0	747	99.40	562.90	25.30	229.20
Pb	300.0	500	13.40	19.23	6.60	13.01
Zn	2800.0	1850	37.10	171.60	70.43	93.04

[a]USEPA (1997); Canadian Compost standard; Ahmed *et al.* (2007)

were within acceptable limits for compost waste. However, the values in Table 4 also indicated that the concentration for Cd in the food, paper and plastic were reaching an amount close to the Canadian compost limits however, they did not exceed the limits. Cadmium is highly toxic metal not known to have any beneficial effects for plants and animals.

The levels of Cu in paper (562.90 mg kg^{-1}) and Zn (171.60) in study among the four heavy metals analyzed were relatively high compared to others; although, they were also well within limits of the compared standards. The relative amount of Cu in paper waste compared to other components may be attributed to the dumping of Cu containing wastes with MSW. Secondly, the relative amount of Cu in paper waste compared to other components can also be linked to the extensive use of this metal (Cu) for paper products for engraving images on paper as prints or illustrations. These might have increased the concentration of Cu metals in paper in the waste from Pangkor Island. However, Cu is a threat to the environment because it does not break down but suspends in water and can travel great distance and over time will accumulate and can be a source of pollution of rivers in the Island. Animals and plant in the vicinity of the Teluk Cempedak waste disposal in Pangkor Island could also be at great risk; likewise few plants will have a chance to survive if this amount reaches levels that cannot be tolerated by these organisms.

The chemical nature of MSW from the Teluk Cempedak disposal site in Pangkor Island shows indication that the waste components have trace quantities of potential pollutant. Figure 3 shows the comparison of the levels of heavy metal concentrations in each of the component of food, paper and plastic waste in Pangkor Island (mean values). The potential pollutant levels in paper tend to be high whilst the food and plastic stream is almost depleted in all four elements. From this result, there is an indication that if these elements between all categories were distributed in proportion to the mass of material, paper waste will aid the distribution of these pollutants across the environment. The environmental compatibility of the waste incineration process mainly depends on the characteristics and

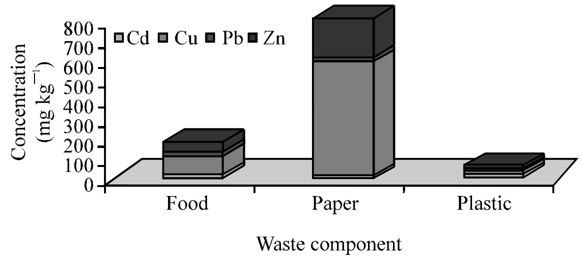

Fig. 3: Comparison of the level of heavy metal in food, paper and plastic waste from Pangkor Island (mean values)

possible applications of the incineration residues. This is of great concern because if these metals were distributed in the waste to a higher level then after incineration the residue containing this metal may constitute a long-term risk for the environment. More attention should be paid on the MSW management in Pangkor Island to avoid heavy metal pollutions.

The landfilling methods need to shift direction toward more minimisation of both short-term and long-term environmental impacts. The landfill is uncontrolled without appropriate technical protection and has neither bottom lining. On the other hand, this method needs to be supplemented with other technologies to meet the regulations and to handle the solid waste in a more environmentally friendly way. Composting at the local level or as a private commercial operation could find a large amount of biodegradable which is about 90.01% in Pangkor. The content of food is 34.12%. The Paper (23.45%) and Plastic (20.52) alone make up 78.09%. With proper segregation the conversion of these organic wastes could help reduce waste stream volumes which would lead to better options and opportunities. However, other factor that contributes equally to the success of such operation must also be understood and acknowledged. The organic material collected from recycling can be directly sent to acomposting plant because it is pure enough (free from heavy metals pollution) to produce compost for agricultural use. In this regard, it is important to maintain purity because using compost from wastes for the cultivation of food increases the possibility of disease transmission which would nullify the purpose of its application. The use of compost in Pangkor Island will be a potentially powerful and will be a locally responsive approach to addressing waste disposal problems.

CONCLUSION

Among the three waste components analysed, paper waste showed the highest concentration of Cu and Zn metal. The content of these metals in paper waste reached 562.9 and 171.6 mg kg^{-1}, respectively. Taking the mean of the overall concentration of the heavy metals contents of all the relevant samples analyzed the result showed that Cd is 16.69 mg kg^{-1}; Cu (229.20 mg kg^{-1}); Pb (13.01 mg kg^{-1}) and Zn (93.04 mg kg^{-1}). In the overall, the values of Cu and Zn were comparatively high compared to the other metals. The mean concentration of Cd (16.69 mg kg^{-1}) and Pb (13.01 mg kg^{-1}) are comparatively less than that obtained for the other metals. Therefore, the order observed for this study for heavy metal concentrations in the waste samples are: Cu>Zn>Cd>Pb. The levels of heavy metal content are: Cd, 16.69 mg kg^{-1}; Cu, 229.20 mg kg^{-1}; Pb, 13.01 mg kg^{-1} and Zn, 93.04 mg kg^{-1} and are in the following order: Cu>Zn>Cd>Pb. The level of heavy metals where within the limits of the USEPA and Canadian standard for compost. Effective waste management in the island requires implementation within the context of an integrated waste management strategy rather than a single option. Attention to integrated waste management options will bring a long term solution that can effectively bring a reduction in waste volumes and will require an option of a thermal treatment of waste (incineration being) complimented with composting. Therefore attention to integrated waste management options were materials needs to be segregated and collected prior to incineration is recommended on the island.

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