Leachate Characteristic of Mosaic Sludge Brick

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Currently, the leachability of heavy metals is one of the issues that has become a main concern towards the environmental impact of the waste incorporation in building material. Mosaic sludge is one of the wastes that have been incorporated into fired clay bricks. In this research, investigation on two types of mosaic sludge have been used which are Bodymill sludge (BS) and Polishing sludge (PS). Mosaic sludge has contributed huge volume of waste to the landfill. During these studies, extraction and leachate of varies heavy metals such as Chromium (Cr), Copper (Cu), Lead (Pb), Cobalt (Co), Vanadium (V), Nickle (Ni), Zinc (Zn), Arsenic (As), Barium (Ba), Mercur y (Hg) and Cadmium (Cd) were carried out by using Method 1311,Toxicity Characteristic Leaching Procedure (TCLP), and method 1312, Synthetic Precipitation Leaching Procedure (SPLP). In this study, characteristics of raw materials were conducted by using X-Ray Florence Spectrometer (XRF). The analysis for all heavy metals were determined by using Atomic Absorption Spectroscopy (AAS), Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and Mercury analyzer. This research study is focus on the toxic leachability of mosaic sludge after being incorporated into fired clay bricks and the results obtained were compared with United state environment protection agency (USEPA, 1996) and Environment Protection Agency Victoria (EPAV, 2005) permissible limit. Four different mixing ratios of mosaic sludge (1, 5, 10, 20 and 30%) were incorporated into fired clay brick and each brick was fired in a heat controlled furnace at elevated temperatures of 1050R"C. Heavy metals in mosaic sludge produced from BS and PS by XRF shows that the chemical composition and concentration of clay soil and mosaic sludge (BS and PS) obtained high value of Titanium oxide (TiO2), Manganese oxide (MnO), ferum oxide (Fe2O3), zinc (Zn), zirconium (Zr) and barium (Ba), which were more than 100ppm. The results obtained shows that both sludges can be incorporated up to 30% as the leachablity of heavy metals concentration were complied with the permissible limit to be classified as "non-hazardous material" according USEPA (1996) and EPAV (2005).

Keywords: bricks, mosaic sludge, leachability, building material

Mosaic is a piece of hard-wearing material finishing that can be found in a form almost of tiles, ceramic and stone for surface interior and outdoor decoration. This craft can be used for decoration everything and it has been a part of the artistic expression of many cultures all over the world. Mosaic process activity like mixing, grinding, cutting, glazing and forming will produce waste that turn into sludge. Mosaic sludge was produced in the form of a slurry, semi-liquid, rock fragments and dust. Mosaic sludge also also consists of colour and heavy metals that can cause the environmental impact. For the ceramic product, most of chemical content are oxides such as silica (SiO_2), alumina (Al_2O_3), lime (CaO) and magnesium oxides (MnO) [1]. According to Malaysia Environment Quality Report [2], the amount of wastes from heavy metals sludge activities are about 103,944.37 metrics tons per year. Malaysia is also facing a problem to find another alternative to deal with sludge disposal as well as to meet the effective cost to preserve the pollutants to the environment. Inorganic content of industrial sludge such as heavy metals should get the specific treatment to prevent environmental pollution. The productions of sludge from industry are the main concern when it is not reused and recycles for any material and the amounts of sludge are arising every year and giving impact to the environment. [3]. Usage of sludge as construction material can convert the waste into useful products thus alleviate the disposal problems. Therefore, recycling mosaic sludge waste could be one of the best alternative methods in terms of environmentally as well as an economical solution.

Bricks are one of the most common building material nowadays due to its properties, high compressive strength, durability, excellent fire resistance, weather resistance, sound insulation, non-combustible, beauty and easy to handle [4-7]. Many attempts have been made to incorporate waste into fired clay brick for example fly ash sludge [8], sewage sludge [9-11], water treatment sludge [12-15], textile mill sludge [16-18] and stone sludge [19]. Additional sludge into brick will provide a positive impact towards the environment as well as improving the performance of brick properties. The aim of this study was to incorporate two types (BS and PS) of the mosaic sludge

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waste in the fired clay brick and to determine the leachability of heavy metals [20-25].

Experimenhtal part

Materials and method

Preparation of raw materials

Mosaic sludge from the dry compress slurry was collected at the Malaysia Mosaic Berhad (MMB) at Kluang, Johor. During sludge waste collection, safety equipment and apparatus was used with care. Clay soil was obtained from Hap Seng Company, Sedenak Johor. These two raw materials were kept properly in a closed container and been storage before being used.

Mosaic sludge and clay soil were dried in the oven for 24 h. After that, the mosaic sludge and clay soil were crushed before being sieved. The mosaic sludge and clay soil was prepared in pellet form before being tested by using X- ray Fluorescence Spectrometer (XRF).

In this leachability test, TCLP [26] and SPLP [27] method were used. Fluid reagent for TCLP was used glacial acetic acid, meanwhile for SPLP used nitric and sulfuric acid (40/60) as fluid reagent. Brick samples were made with different percentages (0, 1, 5, 10, 20 and 30%). Samples brick were divided into four parts and must be crushed to obtain representative sample. After crushed, all samples were sieved through 9.5 mm. The 50 g solid samples were placed in a 2 L high-density polyethylene plastic bottle. The extraction ûuid for 1L contained 5.7 mL of fluid reagent acid with distilled water. The bottles were placed in a rotary extractor at 30 rpm with temperature 22–24°C for 18±2 h. At the end of the extraction, the samples were filtered through 0.7 µm with glass fibre. Finally, the concentrations of heavy metals were measured by using AAS, ICP-MS and Mercury Analyser (fig. 1).

Fig.1. Dilution sample process

Results and discussions

X-ray fluorescence

The characteristic of clay soil and sludge mosaic produced by BS and PS were obtained by using XRF. From table 1 the results shown the highest percentage of chemical composition in clay soil was silica dioxide (SiO_2) and Aluminium dioxide (Al_2O_3) which is between 57.6 to 58.10% and 31.5 to 32.0% respectively. The mosaic sludge also shown similar chemical composition that obtained higest percentage which were silica dioxide (SiO_2) and Aluminium dioxide (Al_2O_3) between 65.5 to 68% and 21.6 to 23.8% respectively. The concentrations of heavy metal for the mosaic sludge and clay soil were shown on table 2. It shows that the clay soil and mosaic sludge (BS and PS) demonstrated high titanium oxide (TiO_2), manganese oxide (MnO), ferum oxide (Fe_2O_3), zinc (Zn), zirconium (Zr) and barium (Ba), were more than 100ppm.

Leachability

Leachability occurred when water or any chemical could percolate through a medium and any permeable material. In this study research, the leachate from the bricks samples was tested. This test was to determine the heavy metals that leach out from the brick, and all the results obtained were compared with United State Environmental Protection Agency (USEPA) and Environmental Protection Agency Victoria (EPAV). All leachability tests were conducted at wastewater laboratory and analytical environment laboratory (FKAAS).

Toxicity Characteristic Leaching Procedure test

The purpose of Toxicity characteristic leaching procedure (TCLP) is to simulate the leaching potential of the waste sample in a sanitary landfill if the waste is being disposed. TCLP was used to determine the hazardous waste or heavy metal that content inside the waste. Leaching tests are widely used as a way for estimating the release potential hazardous from the waste [28, 29]. The test was conducted to make sure all bricks samples that were made satisfy and comply with standards. Table 3 shows the result of TCLP for control brick and mosaic sludge brick. The USEPA SW 864 Method 1311 was used for leachability testing in this research.

Figure 2 shows the heavy metal that exist in BS brick which were Cd, Mn, Fe, Cr, Cu, Pb, Co, V, Ni, Zn, As and Ba. All the heavy metals were complied with the limit allowed, for example Pb for 1% BS brick with 0.567 mg/L shows the highest heavy metal among others, but the amount of the concentration isstill below the permissible limit of USEPA which is 5 mg/L. Other heavy metal such as Mn, Fe, V, Zn,

Table 1
CHEMICAL COMPOSITION

Chemical composition	Formula	Concentration		
		BS	PS	Clay soil
	Original-g	8	8	8
	Added-g	2	2	2
Carbon Dioxide	CO_2	0.10	0.10	0.10
Silica Dioxide	SiO_2	65.77	67.83	57.77
Aluminium Dioxide	Al_2O_3	23.73	21.73	31.80
Sodium Oxide	Na_2O	2.99	3.98	0.47
Potassium oxide	K_2O	1.98	1.78	2.85
Iron oxide/ ferric oxide	Fe_2O_3	1.19	1.25	5.48
Calcium oxide	CaO	1.14	1.04	0.20
Magnesium oxide	MgO	0.92	0.85	0.36
Zirconium dioxide	ZrO_2	0.83	0.35	-
Phosphorus pentoxide	P_2O_5	0.40	0.32	-
Titanium oxide	TiO_2	0.39	0.30	0.63
Barium oxide	BaO	0.28	0.16	-
Chromium	Cr	0 < LLD	0 < LLD	0 < LLD

Table 2
CHEMICAL CONCENTRATION

Chemical composition	Formula	Concentration (ppm)		
		BS	PS	Clay soil
	Original-g	9	9	9
	Added-g	3	3	3
Scandium	Sc	9	20	9
Titanium Oxide	TiO_2	4400	9100	4100
Vanadium	V	41	80	38
Chromium	Cr	470	20	738
Manganese Oxide	MnO	10000	200	100
Ferum Oxide	Fe_2O_3	10900	200	10400
Cobalt	Co	18	6	47
Nickel	Ni	20	8	27
Copper	Cu	46	12	335
Zinc	Zn	238	59	185
Gallium	Ga	20	22	21
Arsenic	As	39	22	49
Rubidium	Rb	137	87	143
Strontium	Sr	132	44	151
Yttrium	Y	25	38	25
Zirconium	Zr	5595	333	6570
Niobium	Nb	34	13	41
Stannum	Sn	15	1	51
Stibium	Sb	44	6	20
Caesium	Cs	9	11	9
Barium	Ba	1325	273	1206
Lanthanum	La	32	22	22
Cerium	Ce	56	44	66
Lead	Pb	28	27	30
Thorium	Th	33	24	33
Uranium	U	12	6	14

Table 3
HEAVY METAL CONCENTRATION BY USING TCLP

TCLP	Control	BS					PS					USEPA	EPAV
Chemical	0%	1%	5%	10%	20%	30%	1%	5%	10%	20%	30%		
Cd	0.017	0.024	0.024	0.028	0.029	0.035	0.020	0.022	0.024	0.024	0.026	1.0	0.8
Mn	0.174	0.072	0.142	0.243	0.095	0.000	0.068	0.009	0.077	0.059	0.065	-	-
Fe	0.196	0.035	0.239	0.652	0.019	0.000	0.0681	0.217	0.235	0.099	0.095	-	-
Cr	0.020	0.023	0.023	0.058	0.012	0.011	0.009	0.008	0.025	0.019	0.010	5.0	20.0
Cu	0.014	0.013	0.017	0.084	0.006	0.011	0.008	0.010	0.010	0.018	0.022	100.0	800.0
Pb	0.650	0.597	0.291	0.194	0.003	0.003	0.004	0.003	0.099	0.002	0.003	5.0	4.0
Co	0.003	0.002	0.002	0.030	0.002	0.003	0.001	0.002	0.002	0.001	0.002	-	-
V	0.512	0.419	0.330	0.015	0.238	0.204	0.217	0.128	0.357	0.089	0.124	-	-
Ni	0.004	0.003	0.002	0.008	0.002	0.002	0.002	0.001	0.002	0.001	0.002	1.3	8.0
Zn	0.353	0.268	0.242	0.504	0.163	0.292	0.263	0.108	0.395	0.117	0.123	500.0	1200.0
As	0.296	0.443	0.343	0.011	0.077	0.085	0.187	0.130	0.413	0.152	0.059	5.0	2.8
Ba	0.448	0.196	0.312	0.379	0.237	0.317	0.231	0.127	0.306	0.092	0.223	100.0	280.0
Hq	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2	0.4

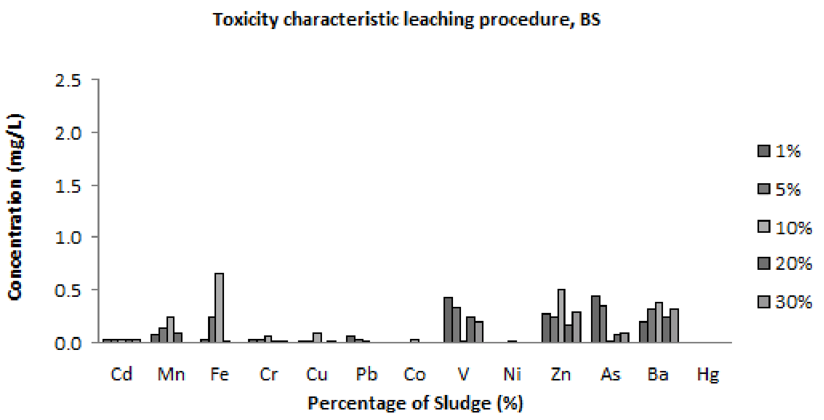

Fig. 2. Heavy metal concentration in BS brick by using TCLP

As and Ba also appear in visible low and acceptable range limits.

The concentration of heavy metal for PS brick by using TCLP was shown in figure 3. PS brick shows lower leachability of heavy metals in Cd, Cr, Cu, Co, Ni, Hq compared to Mn, Fe, V, Zn, As and Ba. However, all heavy metal for PS brick is still within the limit by USEPA and EPAV standard.

Synthetic Precipitation Leaching Procedure (SPLP)

Synthetic Precipitation Leaching Procedure (SPLP) is one of the leachate tests that have been used to determine

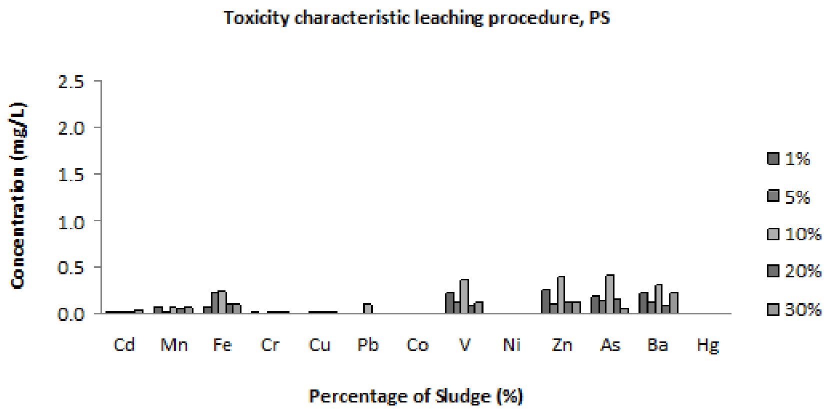

Fig. 3. Heavy metal concentration in PS brick by using TCLP

Table 4
SPLP RESULT

SPLP	Control	BS					PS					USEPA (mg/L)	EPAV (mg/L)
Chemical	0%	1%	5%	10%	20%	30%	1%	5%	10%	20%	30%		
Cd	0.014	0.016	0.019	0.022	0.024	0.030	0.017	0.020	0.021	0.022	0.026	1.0	0.8
Mn	0.002	0.003	0.003	0.005	0.024	0.160	0.013	0.021	0.021	0.026	0.027	-	-
Fe	0.055	0.042	0.043	0.052	0.039	0.056	0.002	0.008	0.028	0.037	0.029	-	-
Cr	0.015	0.002	0.000	0.021	0.001	0.001	0.002	0.001	0.001	0.004	0.001	5.0	20.0
Cu	0.008	0.002	0.001	0.003	0.003	0.004	0.003	0.004	0.001	0.003	0.003	100.0	800.0
Pb	3.138	2.307	2.173	1.821	0.001	0.001	0.002	0.002	2.844	0.002	0.001	5.0	4.0
Co	0.000	0.000	0.000	0.000	0.003	0.002	0.000	0.000	0.000	0.002	0.000	-	-
V	0.634	0.353	0.204	0.007	0.218	0.133	0.229	0.137	0.137	0.088	0.214	-	-
Ni	0.009	0.001	0.001	0.003	0.001	0.002	0.005	0.000	0.001	0.008	0.001	1.3	8.0
Zn	0.651	0.427	0.173	0.171	0.132	0.126	0.146	0.145	0.024	0.117	0.146	500.0	1200.0
As	0.156	0.201	0.115	0.002	0.038	0.023	0.108	0.089	0.077	0.081	0.032	5.0	2.8
Ba	0.430	0.248	0.204	0.192	0.154	0.148	0.140	0.152	0.025	0.113	0.145	100.0	280.0
Hg	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.2	0.4

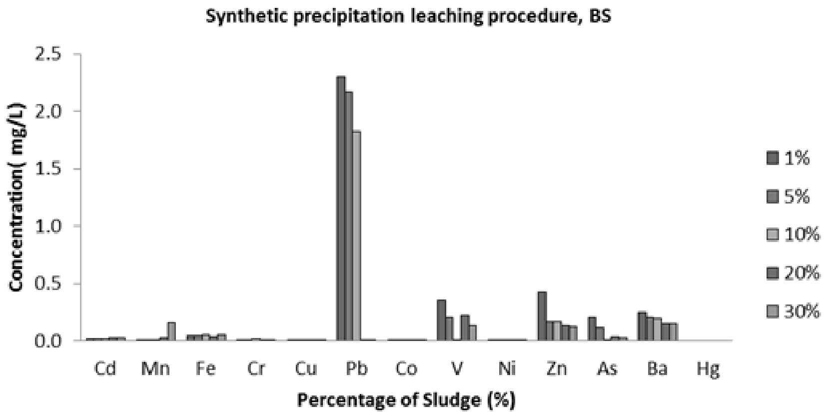

Fig. 4. Heavy metal concentration in BS brick by using SPLP

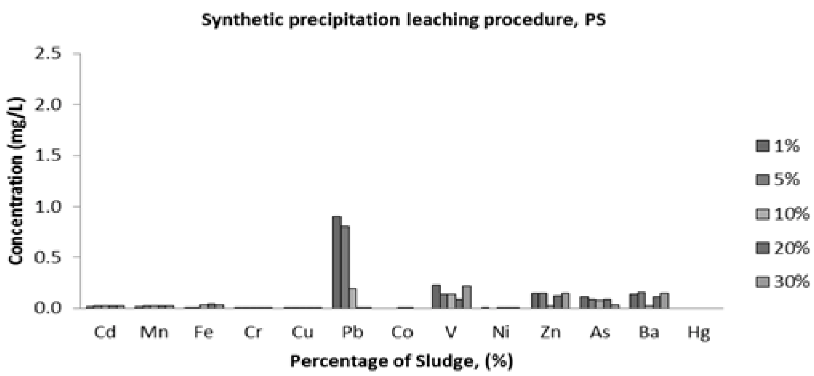

Fig. 5. Heavy metal concentration in PS brick by using SPLP

the potential for soil contamination leach into groundwater. SPLP was designed to determine *in-situ* (ground surface of landfill) contamination that exposed to rainfall with the assumption that rainfall is slightly acidic [30]. In SPLP test, nitric and sulfuric acid (40/60) were used to simulate synthetic rain to adopt the actual situation. Table 4 shows SPLP result for control brick, BS brick and PS brick.

By using SPLP test, figure 3 demonstrated heavy metals concentration in BS brick. Lead, Pb element was the highest at 1% with 2.307 mg/L, followed by 5 and 10% with 2.173 mg/L and 1.821 mg/L respectively. Another element like Cd, Mn, Fe, Cr, Co, and Ni shows very low concentration, and for element V, Zn, As and Ba obtained moderate concentration. However, all heavy metal

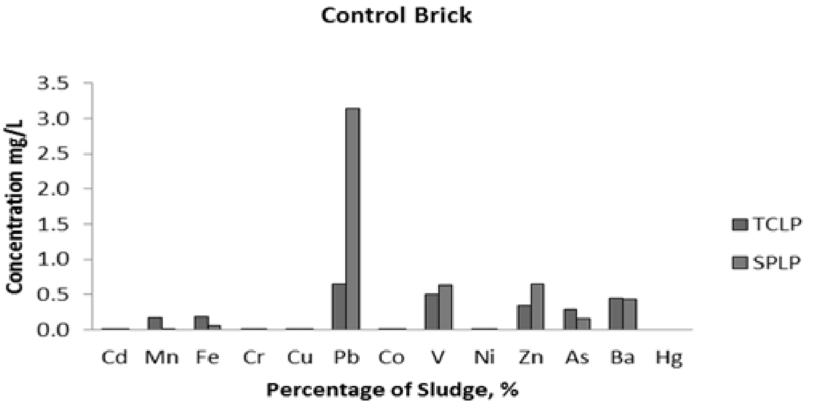

Fig. 6. Comparison between control brick

concentration still under the limitation and comply with the standard.

Figure 5 results found the concentration of heavy metal in PS is high with Pb at 1% brick with 0.902 mg/L, followed by 5% brick and 10% brick with 0.802 mg/L and 0.194 mg/L accordingly and it is beneath limitation of USEPA which is 5 mg/L. Other elements like V, Zn, As and Ba shows the moderate values with 0.113 mg/L to 0.229 mg/L.

Comparison of heavy metal concentration of control brick

According to TCLP and SPLP leachate test, control brick, BS and PS bricks has been tested by using different fluid reagent. Figure 6 shown comparisons between control brick, the highest element was Pb for SPLP with 3.138 mg/L and TCLP with 0.650 mg/L respectively. Another element such as Cd, Mn, Fe, Cr, Cu, Co, As, Ba and V displays the concentration values fromTCLP test was higher compared to SPLP test, even though with slightly different. Nevertheless, Ni and Zn obtained values for SPLP test than TCLP. test. On the other hand, all elements in control brick were in ranges of limitation of USEPA and EPAV.

Conclusions

As a conclusion, leachability of heavy metals concentration from the incorporation of different percentages BS and PS mosaic sludge into fired clay brick were determined. The first objective of this study is to determine the heavy metals concentration of mosaic sludge produced from Bodymill and Polishing process has been fulfilled. The result from XRF shows the highest percentage of clay was silica dioxide (SiO_2) and Aluminium dioxide (Al_2O_3) which is between 57.6 to 58.10% and 31.5 to 32.0% respectively. The mosaic sludge also shows that the highest percentage was demonstrated by silica dioxide (SiO_2) and Aluminium dioxide (Al_2O_3) which is between 65.5 to 68% and 21.6 to 23.8% respectively. Therefore, mosaic sludge is suitable to replace clay in the brick manufacturing process.The concentrations of heavy metal shows that the clay soil and mosaic sludge (BS and PS) highest with Titanium oxide (TiO_2), Manganese oxide (MnO), ferum oxide (Fe_2O_3), zinc (Zn), zirconium (Zr) and barium (Ba), were more than 100ppm. Therefore, the heavy metals of concern in this study due to its concentration are Cadmium (Cd), Manganese (Mn), Ferum (Fe), Chromium (Cr), Copper (Cu), Lead (Pb), Cobalt (Co), Vanadium (V), Nickel (Ni), Zinc (Zn), Arsenic (As), Barium (Ba) and Mercury (Hg). This heavy metals were selected for leachability test which are TCLP and SPLP and then analysed by using AAS, ICP-MS and Mercury analyser. Utilization of sludge from mosaic industry into fired clay brick produce lightweight brick as well as high in compressive strength. Therefore, in this study the optimum percentage of sludge mosaic waste incorporated into fired clay brick was recommended up to 30% of bodymill sludge and polishing sludge. In terms of leachability, with the incorporation of mosaic sludge waste into fired clay brick demonstrated low concentration of heavy metals and safe to be used towards the environment. Overall, the results indicated that this study may help to create an alternative disposal for the sludge waste as well as to provide another low-cost material for the clay brick that could improve the properties. Furthemore, all leachability tests conducted with mosaic sludge brick determine that the heavy metals concentration were complied with the standard and could be classified as “non-hazardous material” according USEPA (1996) and EPAV (2005a).

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