



Leachability of Fired Clay Bricks Incorporated with Sewage Sludge by Using Tank Leaching Test

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Abstract

This research was conducted to fully utilize the sludge that rich in dangerous heavy metals and at the same time act as low cost alternative materials in brick manufacturing. Different series of sludge and clay proportioning ratios were studied, which exclusively involved the addition of sludge with ratios of 0, 1, 5, 10, 20 and 30% of the total weight of sludge-clay mixture. Each molded brick were oven-dried at 105°C for 24 hours followed by heating at 1050°C. The investigation includes determination of heavy metal concentration of the sludge and clay using XRF and heavy metals leachability of the bricks by using Tank Leaching Test according to NEN7345 that has been analyzed by using ICPMS. The leaching behavior of several heavy metals (As, Ni, Cu, Pb, Zn, V, Ba, and Cr) from incorporated sludge into fired clay bricks shows to be insignificant and far below the USEPA regulations limits which fulfill the general requirement for usage of clay brick in construction and comply with the leaching standard limit. As a conclusion, the utilization of sewage sludge can reduce the disposal to landfill and reduce the leachability of sludge which can effect environment and human.

Keywords: Heavy metals; leachability; sewage sludge; sewage sludge brick; waste management.

1. Introduction

Sludge from wastewater treatment plant is produce from human waste from domestic, commercial and industrial sources. It has been characterized by its high moisture content, low calorific value, and low bulk density, which result in a low conversion efficiency [1]. In Malaysia, with the rapid development growth in this country, volume of sludge produced from wastewater treatment process proportionately increase. Based on [2] research, about 5.3 million m³ per year sludge was produces by a national sewage company such as Indah Water Konsortium (IWK).

In recent years, disposal method such as landfill has been widely used in order to dispose the larger amount of sludge. With the increasing amount of sludge production, landfill method become an improper solution and it seems obvious that recovery and reusing of the sludge as raw and building materials can be considered as alternative method. The awareness of environmental problem has forces government, local authorities and utilities for management to search for new alternative process or solutions for future waste management strategies. According to some studies [3,4] that has successfully utilize different types of sludge which obtain provision results. Sludge often associated with human waste from residential sludge, however sludge is also produced by industrial waste, hospital waste, wastewater treatment plant, runoff from the street, farmland and some cases from landfill leachate.

However, the disposal of these sludge will become a critical issue due to public concern and limited availability of land thus alternative disposal method is essential as landfill is not an ideal disposal method anymore for this waste [5, 6]. Therefore, recycling sewage

sludge could be one of the best alternative methods in terms of environmentally as well as economically solution. Attempts have been made to incorporate waste in the production of bricks.

Brick manufacturing is a historic industry and the production process is well established. Brick also the oldest building materials that have many advantages including have attractive appearance, high compressive strength and high durability, excellent in fire and weather resistance, good thermal insulators and easy to handle [7]. However, apart from the advantages in the properties and the potential usage of different types of sludge, heavy metals such as zinc, lead, iron and cadmium can be found in these waste materials [8,9]. The information regarding chemical properties of fired clay brick with sewage sludge is required to ensure it can be safely utilized in certain application. In order to provide the information, the development of a whole suite of data; lab data will be conducted to convince the engineering community that the waste material will behave in a certain way. Therefore, this research focuses on the formulation of sewage sludge by incorporating the correct ratio of the sludge in replacing clay soil to fully utilize the waste potential but at the same time controlling the toxic leachability of the waste material and also becoming an alternative disposal method for the waste.

2. Materials and Methods

The disposed sludge was collected from Wastewater Treatment Plant A and B and the clay from a clay factory at Johor, Malaysia. The characterization of materials were conducted by using X-Ray Fluorescence (XRF). The samples were prepared by incorporating 0%, 1%, 5%, 10%, 20% and 30% sludge into fired clay brick. The

leachability of heavy metals from each samples were conducted by using Tank Leaching Test according to NEN 7345 method. In the NEN 7345 method, each of sample was soaked into a polyethylene container and filled with acidic water with HNO₃ at pH=4. The sample was completely submerged with the fluid. The leachate was collected after 6hours, 1day, 1day 6hours, 4days, 9days, 16days, 36days and 64days as per NEN 7345. The leachate was removed and replaced with fresh extractions. Triplicate samples from all the leachates were produced and analysed for heavy metals using Inductive Coupled Plasma Mass Spectrophotometer (ICPMS). Sewage sludge waste for both type was mixed with clay according the ratio of 1%, 5%, 10%, 20% and 30%.

Table 1: Mix ratio of brick manufacturing

Sample	Mix Ratio	
	Sludge (kg)	Clay (kg)
Control brick (CB)	0.00	3.000
Sludge brick 1 (SB1%)	0.030	2.970
Sludge brick 5 (SB5%)	0.150	2.850
Sludge brick 10 (SB10%)	0.300	2.700
Sludge brick 20 (SB20%)	0.600	2.400

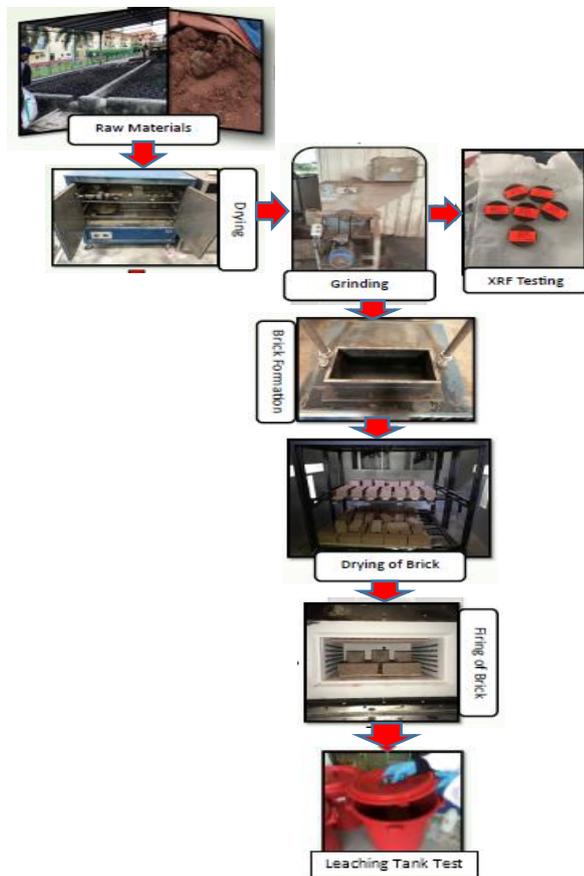


Fig. 1: Flow diagram testing methodology

3. Result and Discussion

3.1. X-ray Fluorescence (XRF)

Figure 2 shows concentration of heavy metals in raw clay soil and Type A of sewage sludge. From the result, it shows that sewage sludge contains higher concentration of Zinc (Zn) with 1030 ppm, Barium with 707 ppm, Copper (Cu) with 89 ppm and Arsenic (As) with 83 ppm respectively. Meanwhile for clay shows slightly different concentration of heavy metals that higher compared to sewage sludge which are Barium (Ba) with 366ppm, Zinc (Zn) with

260ppm, Vanadium (V) with 161 ppm and Arsenic (As) with 105 ppm.

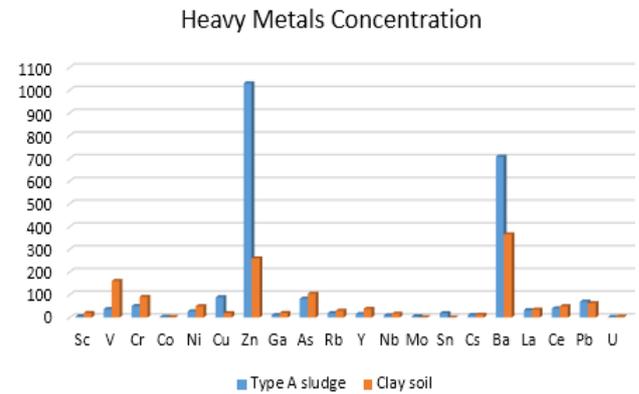


Fig. 2: Heavy Metals Concentration for clay soil and Type A sludge

Meanwhile, Figure 3 shows the concentration of heavy metals between clay soil and Type B sewage sludge. From the result presented that the highest concentration of heavy metal in Type B sewage sludge is Barium (Br) with value 1271 ppm followed by Zinc (Zn) which is 927 ppm, Copper (Cu) with 101ppm and Lead (Pb) with 75 ppm respectively.

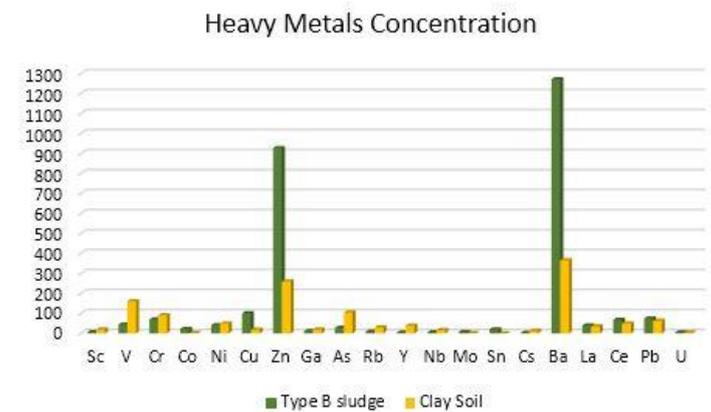


Fig. 3: Heavy Metals Concentration for clay soil and Type B sludge

3.2. Leachability Analysis

Figure 4 shows heavy metal concentration results for the control brick immersed from 6hours to day 64. It shows that the control brick had the highest levels of Barium (Ba) on day 64 with 0.7 mg/L followed by Barium (Ba) on day 16 with 0.482 mg/L among all the heavy metals. Zinc (Zn) at day 9 shows the highest value with 0.525 mg/L and gradually decreased until day 64 (0.2 mg/L). Other heavy metals such Cu, Pb, V, Ni, Cr, and As showed very little amount and complied with USEPA standards.

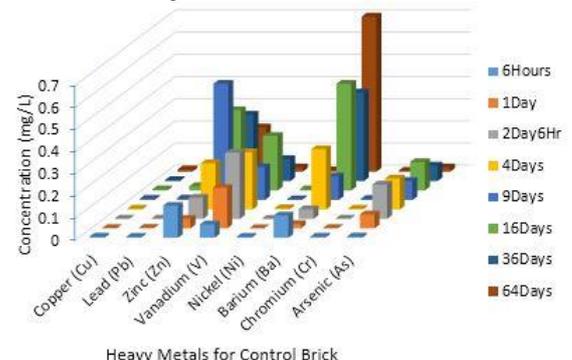


Fig. 4: Comparison of heavy metal concentrations in Control Brick for different leaching periods using Tank Leaching Test

Figure 5 shows the heavy metal concentration of Type A sludge brick (1%). The result obtained showed that Barium (Ba) has the highest concentration of heavy metal obtained compared to other heavy metals with 0.7 mg/L on day 64 and 0.4 mg/L on day 36 followed by Zinc (Zn) with 0.3 mg/L on day 36. Other heavy metals showed similar value below 1 mg/L and far from the exceeding limits. Nevertheless, all heavy metals for Type A sewage brick 1% complied with the standards.

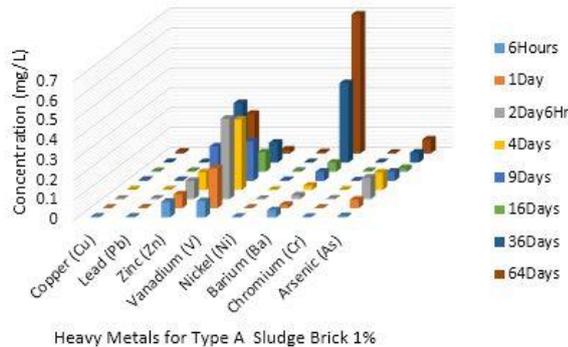


Fig. 5: Comparison of heavy metal concentrations in Type A sludge brick 1% for different leaching periods using Tank Leaching Test

The heavy metal concentration of Type A sewage brick (5%) was shown in Figure 6. The result obtained showed that Type A sludge brick (5%) was higher in Barium (Ba) on day 36 with 0.3 mg/L and slightly decreased until day 64 at 0.2 mg/L. Higher concentration of Vanadium was also detected with 0.422 mg/L on day 4 and then the value decreased continuously until day 64 with 0.02 mg/L. Other heavy metals were found below 1mg/L and within the standard limits.

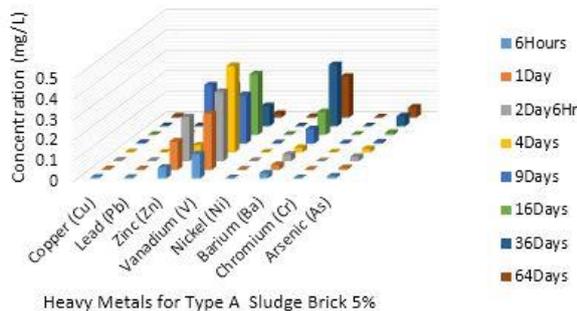


Fig. 6: Comparison of heavy metal concentrations in Type A sludge brick 5% for different leaching periods using Tank Leaching Test

Figure 7 shows the heavy metal concentration in Type A sludge brick (10%) from 6 hours to day 64. The results showed that Barium (Ba) was the highest on day 64 at 0.4 mg/L and 0.3 mg/L on day 36. Vanadium (V) was detected to be the second highest heavy metal after Barium (Ba) with 0.244 mg/L on 2day 6hours and decreased until day 64 with 0.02 mg/L. Other heavy metals were found in low concentrations not exceeding 1 mg/L. Furthermore, all heavy metals satisfied the standards.

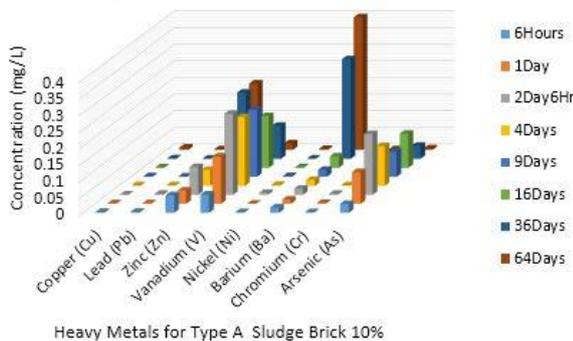


Fig. 7: Comparison of heavy metal concentrations in Type A sludge brick 10% for different leaching periods using Tank Leaching Test

Figure 8 shows the heavy metal concentration of Type A sludge brick (20%). A high concentration of Barium (Ba) was detected on 6 hours at 0.175 mg/L. However, Barium (Ba) started to decline from day 1 until 2day 6hours immersed but instantly increased until day 64 with 0.3 mg/L. Vanadium (V) also demonstrated high value on day 1 at 0.202 mg/L but later dropped significantly until day 64 at 0.01 mg/L. On the other hand, Zinc (Zn) result peaked on day 9 at 0.209 mg/L but then the value was constant from day 16 and above at 0.1 mg/L. Other heavy metals measured showed low concentration and complied with the standards.

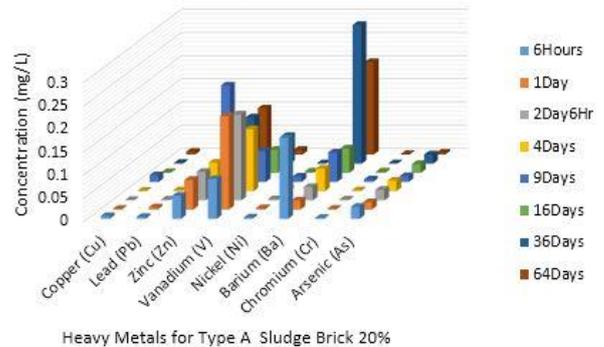


Fig. 8: Comparison of heavy metal concentrations in Type A sludge brick 20% for different leaching periods using Tank Leaching Test

Heavy metals measurement of Type A sludge bricks 30% was illustrated in Figure 9. Zinc (Zn) showed the highest value compared to other heavy metals on day 9 with 0.396 mg/L and continuously decreased until day 64 with 0.10 mg/L. Vanadium (V) showed a higher value on day 16 with 0.313 mg/L and constantly decreased until day 64. However, all other heavy metals measured complied with USEPA requirement standards.

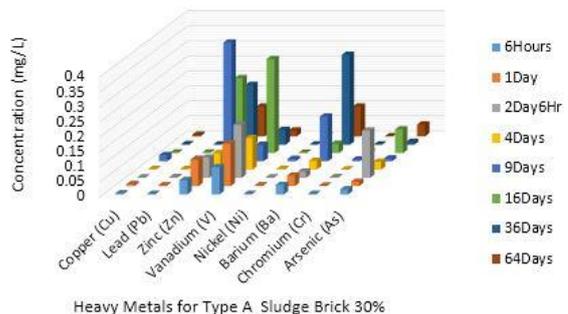


Fig. 9: Comparison of heavy metal concentrations in Type A sludge brick 30% for different leaching periods using Tank Leaching Test

The results for Type B sludge brick (1%) were shown in Figure 10. The highest heavy metal concentration was Zinc (Zn) with 0.525 mg/L on day 9, but then the value decreased until day 64 with 0.2 mg/L. Barium (Ba) was also slightly high at 0.70 mg/L on day 64. On the other hand, Vanadium was peaked on 2day 6hours at 0.299 mg/L but then remained constant till day 36. Other heavy metals were detected in very low concentration and complied with the required standards.

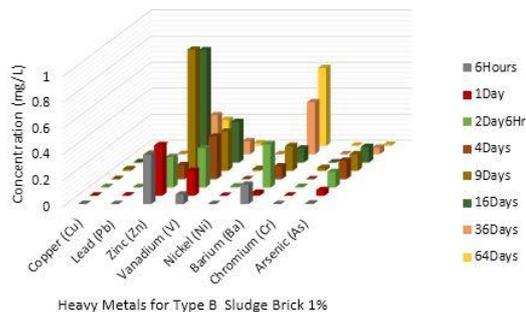


Fig. 10: Comparison of heavy metal concentrations in Type B sludge brick 1% for different leaching periods using Tank Leaching Test

The results of the heavy metal concentration of Type B sludge brick (5%) were illustrated in Figure 11. From the graph shows the heavy metal concentration of Type B sludge brick (5%) from 6hours to day 64. The result obtained showed that the highest peak was Barium (Ba) with 0.5 mg/L on day 64 and followed by Barium (Ba) with 0.4 mg/L at day 36. Zinc (Zn) showed higher value on day 36 with 0.3 mg/L and followed by day 64 for Zinc (Zn) with 0.2 mg/L. Other heavy metals show the lowest result and far below the USEPA standard limit.

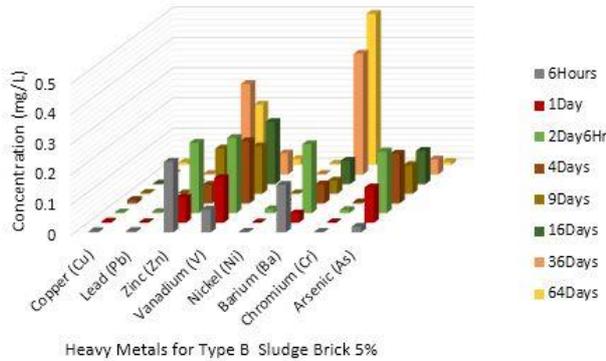


Fig. 11: Comparison of heavy metal concentrations in Type B sludge brick 5% for different leaching periods using Tank Leaching Test

Figure 12 shows heavy metal concentration of Type B sludge brick (10%) with unit concentration miligram/liter against types of heavy metals from 6hours to day 64. Barium (Ba) showed a high value of 0.3 mg/L on day 36 before starting to increases on day 64. The second highest heavy metal detected was Zinc (Zn) with 0.349 mg/L on day 16 and remained decreased until day 64 with 0.2 mg/L. As for Vanadium (V), the result was peaked on 2day 6hours with 0.273 mg/L before remaining constant on day 4 to day 16. Other heavy metals were below 0.40 mg/L until day 64. Thus, all heavy metals were satisfied and below the standard limits.

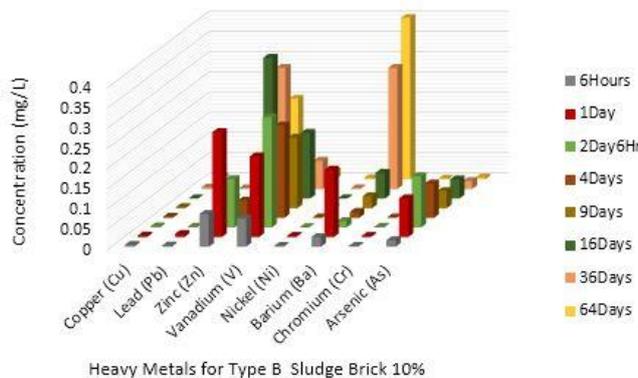


Fig. 12: Comparison of heavy metal concentrations in Type B sludge brick 10% for different leaching periods using Tank Leaching Test

Figure 13 shows Type B sludge brick (20%) concentration of heavy metals. The highest heavy metal concentration was Barium (Ba) with 0.13 mg/L on day 36 and followed by Vanadium (V) with 0.33 mg/L on 2 day 6 hours. Vanadium (V) remained constant on day 4 with 0.303 mg/L. Arsenic (As) showed a peak value on day 1 with 0.138 mg/L before being reduced to 0.004 mg/L on day 64. Zinc (Zn) values were high on day 9 and day 16 with 0.243 mg/L and 0.115 mg/L respectively. On the other hand, all heavy metals were below the limits mentioned in USEPA.

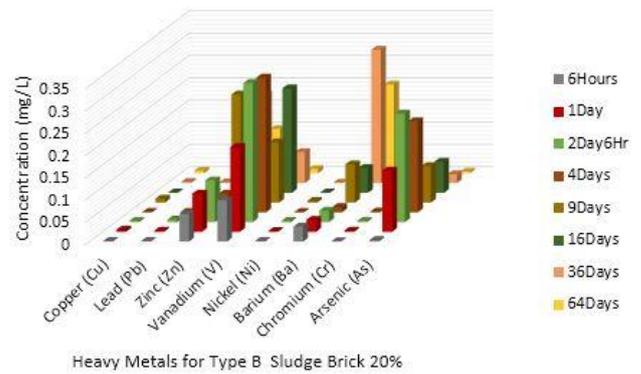


Fig. 13: Comparison of heavy metal concentrations in Type B sludge brick 20% for different leaching periods using Tank Leaching Test

The result from Figure 14 shows the heavy metal concentration of Type B sludge brick (30%) from 6 hours to day 64. Day 36 shows the highest concentration of Barium (Ba) with 0.13 mg/L among other heavy metals and it started to decline at day 64. As for Vanadium, the concentration value was 0.174 mg/L on day 1, but then remained constant on 2 day 6 hours and day 4. Zinc (Zn) peaks were high on day 36 with 0.2 mg/L. As for Arsenic (As), the results showed high reading at 1day with 0.133mg/L and remained constant until day 16. Nevertheless, all heavy metals still satisfied and complied with the standard limits.

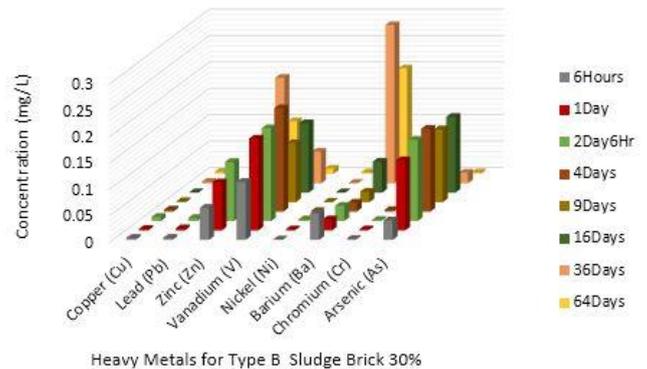


Fig. 14: Comparison of heavy metal concentrations in Type B sludge brick 30% for different leaching periods using Tank Leaching Test

3.3. Summary of Tank Leaching Test Result

The tank leaching test showed that by incorporating sewage sludge up to 30% into fired clay bricks, the Barium concentration could be increased up to 0.7 mg/L but then decreased and remained constant till day 64. This could be due to the reaction between the leaching fluid and the brick samples. Based on the XRF results it showed that the Zn and Barium element coming from sewage sludge was higher compared to clay soil. From the leachate test Zinc shows the highest concentration with 0.525 mg/L which is the same metal obtained on XRF testing. Zinc is a lustrous bluish-white metal which found in group of the periodic table. At ordinary temperatures, it is brittle and crystalline but when heated between 110°C and 150°C it becomes ductile and malleable. It is a fairly reactive metal that will combine with oxygen and other non-metals, and will react with dilute acids to release hydrogen [10]. Another element that appears in most bricks is Vanadium. Vanadium is a common element that normally occurs in clay as a complex mineral [11]. The trend for the long-term leachability test (tank test) is that for the first few weeks, the amount of heavy metals concentration was leaching out from the brick samples and increasing steadily before decreasing until day 64. According to [12], this is an active phase which then decreases towards the end of this phase because of the matured progress. Based on [13], the heavy metal concentration amount was reduced

by exposing the sludge to acid fluid for a long period of time. In addition, [13] mentioned that changes in heavy metal concentrations depend on the metal loss through leaching and the overall concentration of metals is due to the organic matter destruction. Other than that, the changeable condition will also affect leachability.

4. Conclusion

The concentration of heavy metals elements such as Cu, Pb, Zn, V, Ni, Ba, Cr and As shows contained the highest concentration value in Type A and Type B sludge brick. The casting process of bricks were involved different design mix proportions involved 0% of sewage sludge (control sample), 1%, 5% and 10% 20% and 30% of sewage sludge. After 64 days conducting the tank leaching test on specimens of sewage bricks, the results obtained from ICPMS test shows that the concentrations of all heavy metal elements detected were significantly lower than the limit specified by the USEPA. As a conclusion, the utilization of sewage sludge up to 30 % to be incorporated into fired clay bricks are potentially feasible and these materials are safe to be implemented as a part of the building materials.

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