Leaching of Heavy Metals Using SPLP Method from Fired Clay Brick Incorporating with Sewage Sludge

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Abstract. Sewage sludge is a by-product generate from wastewater treatment process. The sewage sludge contains significant trace metal such as Cr, Mn, Ni, Cu, Zn, As, Cd and Pb which are toxic to the environment. Sewage sludge is disposed of by landfilling method. However, this option not suitable because of land restriction and environmental control regulations imposed. Therefore, sewage sludge from wastewater treatment plant was incorporated into fired clay brick to produce good quality of brick as well as reducing heavy metals from sludge itself. Sewage sludge with 0%, 1%, 5%, 10% and 20% of were incorporated into fired clay bricks and fired at 1050°C temperature with heating rates of 1°C/min. The brick sample then crushed and sieved through 9.5 mm sieve for Synthetic Precipitation Leaching Procedure (SPLP). From the results, incorporation up to 20% of sewage sludge has leached less heavy metals and compliance with USEPA standard.

1. Introduction

Sewage sludge is a final product from wastewater treatment processes and carried away by the drainage system. Wastewater likewise named as sewage effluent can be perceived as used water originating from domestic, industrial and sewage runoff. Sewage generated from sources point is being conveyed via sewerage systems to treatment facility [1]. According to previous studies, important heavy metals from sewage sludge which can be dangerous to human health includes arsenic, nickel, cadmium, chromium, lead, mercury and nickel [2]. Same studies have found high concentration of heavy metals and radionuclide also gives effect towards human health [3]–[5]. A significant amount of post-consumer sewage sludge waste is directly thrown away into landfills. However, this method may cause many problems towards the environment such as groundwater pollution from landfill leachate, odor emission and soil contamination [6]. Therefore, instead of disposing directly to landfill, recycling and reuse it as a raw material to be incorporated with the clay brick is an alternative disposal method.

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Since building materials such as clay brick are produced by using existing natural resources, the feasibility of clay allows its combination with different types of wastes without significant modification of the production process and final product usage [5-6]. Many researchers have successfully attempted the utilization of sewage sludge into fired clay bricks, however, the study on leaching effects still not adequate [7-8]. With rising social awareness about toxic emissions from the sludge and the expanding worry over the disposal of sludge onto landfill, it seems evident that the incorporation of waste as a building and construction raw material can be considered as a vital stride in the correct course [9-10].

Therefore, sewage sludge from wastewater treatment plant was incorporated into fired clay brick to provide an alternative disposal method, while producing adequate brick. The minimization of heavy metal leachability to the environment also was conducted by using Synthetic Precipitation Leaching Procedure (SPLP) [11].

2. Materials and methods

2.1. Material
The sewage sludge waste as in Figure 1 was collected at wastewater treatment plant at Indah Water Konsortium Parit Raja, Johor. Clay soil was obtained at Yong Peng, Johor. Both of the materials, clay soil and sludge were kept properly in a closed container. In this study, the leachate from the brick samples was tested and the results obtained were compared with those from the United State Environmental Protection Agency (USEPA).

![Figure 1. Sludge collection from wastewater treatment plant](image)

2.2. Sample Preparation and Heavy Metals Determination
Figure 2 summarizes the sample preparation process and testing in this study. Upon delivery, fresh sewage sludge and clay soil were oven dried separately at 105°C within 24 hours. This process is to remove biological bound water of raw materials and break degradation process of the sewage. The preliminary work was done by analyse sludge using X-Ray Fluorescence (XRF) method to determine heavy metals concentration of the sample. Therefore, the result from XRF have shown that Chromium (Cr), Manganese (Mn), Nickel (Ni), Copper (Cu), Arsenic (As), Zinc (Zn), Lead (Pb) and Cadmium (Cd) are the investigate parameters in this study.

2.3. Brick Manufacturing Process
Trial mix was conducted to determine suitable percentage of sewage sludge content for brick manufacturing. The ratio of sludge was calculated based on the weight of the sludge. Therefore, the manufactured bricks were designed as Control Brick (CB) for brick without sludge waste, SSB1%, SSB5%, SSB10% and SSB20% for brick with 1%, 5%, 10% and 20% of sludge waste, respectively. Brick manufacturing process was started by mixing clay soil with 0% up to 20% of waste with water. The wet mixed sample was then pressed into mould sizes 215 mm x 102.5 mm x 65 mm with pressure...
of 2500 psi. The prepared brick then were kept at room temperature for 24 hours and followed by another 24 hours for oven drying period. The dried bricks finally were fired in a furnace at 1050°C for 18 hours.

2.4. Leachability Test for Manufactured Brick

Synthetic Precipitation Leaching Procedure (SPLP) was conducted according to Method 1312 [7]. The brick samples were divided into four parts and crushed to obtain representative samples. The SPLP (Method 1312) leaching fluid is simulating an acid rain and prepared by diluting sulphuric and nitric acid (60/40 weight percent mixture) \( \text{H}_2\text{SO}_4/\text{HNO}_3 \) into distilled water until the pH was 4.2 ± 0.05. The leaching fluid and samples were put inside the sampling bottle. The bottles were placed in a rotary extractor (Figure 3) at 30 rpm with 22°C to 24°C for 18 ± 2 hour. At the end of the extraction, the samples were filtered through 0.7 µm with glass fibre (Figure 4) and were sent to analyse using inductively coupled plasma mass spectrometry (ICP-MS). The investigate parameters are Chromium (Cr), Manganese (Mn), Nickel (Ni), Copper (Cu), Arsenic (As), Zinc (Zn), Lead (Pb) and Cadmium (Cd).

![Figure 2. Process used to prepare the samples](image-url)
3. Results and Discussion

3.1. Characteristic of Raw Materials

Table 1 shows the heavy metals concentration using XRF analysis. From the analysis, several parameters show the heavy metal accumulates in the sludge where Mn and Zn are the highest heavy metals with 330 mg/L and 132 mg/L. The lowest heavy metal traced in sludge is Cd with 5 mg/L. Meanwhile, Mn and Cr shows the highest heavy metal in clay soil with 124 mg/L and 100 mg/L. Cd and As are the lowest heavy metals in clay soil. When compares to USEPA, several parameters in both raw materials are over the limitation. Therefore, these parameters are the matter of concern and were selected to be analysing for the next SPLP test.

Table 1. Heavy metals concentration of raw materials using XRF analysis

| Heavy Metals | Concentration Limit (mg/l) (USEPA) | Concentration (mg/l) SSW | Concentration (mg/l) Clay Soil |
|--------------|-----------------------------------|--------------------------|-----------------------------|
| Chromium (Cr)| 20                                | 49                       | 100                         |
| Manganese (Mn)| 260                             | 330                      | 124                         |
| Nickel (Ni)  | 8                                 | 16                       | 15                          |
| Copper (Cu)  | 800                               | 15                       | 23                          |
| Zinc (Zn)    | 1200                              | 132                      | 33                          |
| Arsenic (As) | 2.8                               | 55                       | 8                           |
| Cadmium (Cd) | 0.8                               | 5                        | 0.1                         |
| Lead (Pb)    | 5                                 | 56                       | 30                          |

3.2. Leachability for Sewage Sludge Brick

Table 2 shows the leachability result for sewage sludge brick. From the Table 2, Mn and Zn were the highest element traced in Control brick. Meanwhile SSB1%, SSB5%, SSB10% and SSB 20% show the same results where Mn and Zn were the highest element traced in the sample. Others element like Cd and Pb did not leached any or little heavy metals from the brick samples. The results have shown that after incorporation sewage sludge waste into fired clay brick, all the parameters did not exceed USEPA limit. This is due to the phenomenon of heavy metals in sludge is completely vaporised at
high firing temperature during sintering process, therefore could reduce the heavy metals inside the brick [7].

| Heavy Metals     | Control | SSB1% | SSB5% | SSB10% | SSB20% | USEPA (mg/l) |
|------------------|---------|-------|-------|--------|--------|--------------|
| Chromium (Cr)    | 0.002   | 0.004 | 0.004 | 0.004  | 0.027  | 20           |
| Manganese (Mn)   | 0.518   | 1.280 | 1.250 | 1.220  | 1.120  | 260          |
| Nickel (Ni)      | 0.012   | 0.004 | 0.005 | 0.005  | 0.005  | 8            |
| Copper (Cu)      | 0.006   | 0.013 | 0.017 | 0.015  | 0.021  | 800          |
| Zinc (Zn)        | 0.403   | 0.681 | 0.637 | 0.682  | 0.689  | 1200         |
| Arsenic (As)     | 0.002   | 0.220 | 0.378 | 0.437  | 0.453  | 2.8          |
| Cadmium (Cd)     | n.d     | n.d   | n.d   | n.d    | n.d    | 0.8          |
| Lead (Pb)        | n.d     | 0.004 | 0.003 | n.d    | n.d    | 5            |

n.d : Not Detectable

4. Conclusion

As a conclusion, the heavy metals leachability by incorporating different percentages of sewage sludge waste into fired clay brick properties was determined. From the result, concerning on the leachability properties, it can be concluded that incorporation of sewage sludge waste up to 20% into fired clay brick could reduce the heavy metals significantly from the sludge. The results also showed that sewage sludge incorporated into fired clay brick could minimize the toxicity of the heavy metals exist in the raw sludge waste. Therefore, it can be concluded that by incorporating sewage sludge could be an alternative as a replacement raw material for brick manufacturing.

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