PAPER • OPEN ACCESS

Investigation on Properties and Leachability of Sewage Sludge from Wastewater Treatment Plant Incorporated in Fired Clay Brick

To cite this article: N S Abdul Salim *et al* 2018 *IOP Conf. Ser.: Mater. Sci. Eng.* **374** 012096

Investigation on Properties and Leachability of Sewage Sludge from Wastewater Treatment Plant Incorporated in Fired Clay Brick

N S Abdul Salim[1], A Abdul Kadir*[1,2], M A Kamarudin[1], M H Fadzli Zaidi[1] and M M A B Abdullah[2,3]
[1]Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia, Johor, Malaysia
[2]Center of Excellence Geopolymer and Green Materials (CEGeoGTech), School of Materials Engineering, Universiti Malaysia Perlis (UniMAP), Perlis, Malaysia
[3]Faculty of Engineering Technology, Universiti Malaysia Perlis, Perlis Malaysia

E-mail: aeslina@uthm.edu.my

Abstract. Sewage sludge is produced from wastewater treatment plant that often dumped into landfill sites, lagoons or together with municipal waste. Apart from this, the disposal of this sewage sludge becoming a problem for environment. Thus, an alternate method is needed to overcome the issue. Therefore, the objective of this study is to determine the possibility of incorporating sewage sludge in fired clay brick and to compare with normal fired clay brick. The characteristics of sewage sludge were determined by using an X-ray Fluorescence. The mixing percentage used was 0%, 1%, 5%, 10%, 20% and 30%. The physical and mechanical properties were determined as to obtain the condition according to it mixing percentages. Based on physical and mechanical properties, the sewage sludge brick complies with the standard except for SSB30% where the compressive strength does not meet the minimum requirement limit of compressive strength. However, in terms of leachability of this sewage sludge brick also resulted that the heavy metals leach out comply according to USEPA standard. The development of fired clay brick by using sewage sludge can reduce the dependency towards land use and will reduce the impact of the sewage sludge to the environment.

1. Introduction

Sewage sludge consists of by-products of wastewater treatment which is a mixture of water, inorganic and organic materials that coming from various sources such as from domestic sewage [1]. The amount of sewage sludge produced is steadily increasing with a population and still rising rapidly. About 3 million metric tons of sewage sludge are produced annually and it has been estimated to be increases to 7 million metric tons in the year 2020 in Malaysia. Due to the growth of urbanization, an increase of population and a sign of economic development has led to the production of high amounts of sewage sludge. In addition, the major method of disposal of sewage sludge is currently deposited with its storage and agricultural application which are deposited in landfill sites, lagoons or together with municipal waste [2]. Due to the shortage of disposal facilities, sewage sludge is often disposed in open fields that resulted in serious problems because of heavy metals that leached out into groundwater, surface water and soils [3]. According to the other studies, sewage sludge has been used by incorporating it into fired clay brick in order to obtain the properties and leachability of heavy metals. The utilization of the sewage sludge in fired clay bricks could produce a good quality of brick. Therefore, recycling the wastes in the brick production appears to be a viable solution to environmental pollution and also economical option to design of green building [4].

2. Materials and methods

Sewage sludge was collected from wastewater treatment plant which is located in Johor, Malaysia where it produced from the residential area while the clay soil was bought from the brick factory in order to produce fired clay brick incorporated with sewage sludge. These raw materials then dried in the oven for 24 hours with 105°C of temperature before crushing process. Then, X-ray Fluorescence (XRF) test was conducted on sewage sludge and clay soil as to obtain the chemical composition and concentration of heavy metals. The sample of bricks was produced in the specific size of the mold by mixing together of sewage sludge and clay soil by following the percentages of mixing weight of brick manufacturing and volume of water used. The bricks that have been formed then dried in the oven for 24 hours with 105°C of temperature. Then, the bricks that have been dried were fired in the furnace with 1050°C for 24 hours. The bricks that completely fired according to the different percentages of sewage sludge used were tested for physical and mechanical properties such as compressive strength, water absorption, shrinkage, density and also the initial rate of absorption [5].

While the leachability of heavy metals of fired clay brick was conducted by using Static Leachate Test (SLT) according to the different percentages of sewage sludge used. Static leachate test was performed as to obtained the leachability of heavy metals from sewage sludge that incorporated in fired clay brick according to NEN7345 method. The leachability of heavy metals were obtained through Inductive Coupled Plasma-Mass Spectrometer (ICP-MS). The duration of the Static Leachate Test was conducted were 6-hours, 1-day, 2.25-days, 4-days, 9-days, and 16-days. To ensure it is safe in terms of leachability, it is significant to carry out a comprehensive environmental assessment of new building products integrating with waste materials [6]. Heavy metals that leached from brick that incorporating with sewage sludge may have a potentially negative impact on human health and environmental quality by leaching into groundwater and surface water which could give water pollution issues.

3. Results and Discussion

3.1. Characteristic of Raw Materials

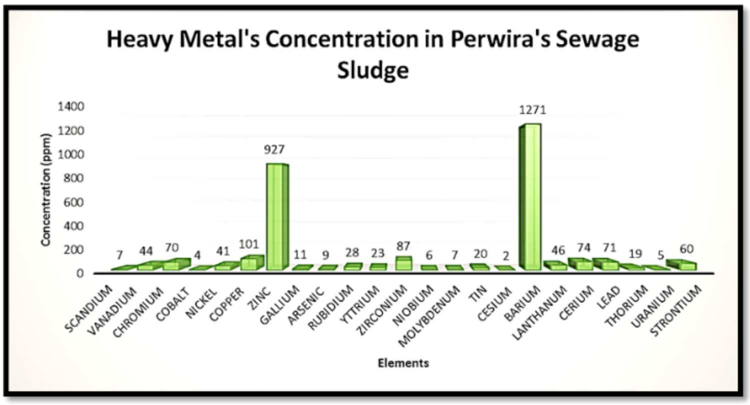


Figure 1. Concentration of heavy metals in sewage sludge versus percentage of concentration by using the *Standardless method.*

The concentration of heavy metals was obtained by X-ray Fluorescence testing using the Standardless method. The elements of heavy metals that found in sewage sludge are Scandium (Sc), Vanadium (V), Chromium (Cr), Cobalt (Co), Nickel (Ni), Copper (Cu), Zinc (Zn), Gallium (Ga), Arsenic (As), Rubidium (Rb), Yttrium (Y), Zirconium (Zr), Niobium (Nb), Molybdenum (Mo), Tin (Sn), Cesium (Cs), Barium (Ba), Lanthanum (La), Cerium (Ce), Lead (Pb), Thorium (Th), Uranium (U) and Strontium (Sr). Barium (Ba), Zinc (Zn) and Copper (Cu) were recorded with the highest value of concentration which was 1271 ppm, 927 ppm, and 101 ppm respectively while the other elements were recorded with less than 100 ppm value of concentration.

While the elements that found in clay were Scandium (Sc), Vanadium (V), Chromium (Cr), Cobalt (Co), Nickel (Ni), Copper (Cu), Zinc (Zn), Gallium (Ga), Arsenic (As), Rubidium (Rb), Yttrium (Y), Zirconium (Zr) Niobium (Nb), Molybdenum (Mo), Cesium (Cs), Barium (Ba), Lanthanum (La), Cerium (Ce), Lead (Pb), Thorium (Th), Uranium (U) and Strontium (Sr). The highest concentration of heavy metals with value more than 100 ppm were Barium (Ba), Zirconium (Zr), Zinc (Zn), Vanadium (V) and Cerium (Ce) which were 366 ppm, 274 ppm, 260 ppm, 161 ppm and 105 ppm respectively while the other elements were recorded with a value lower than 100 ppm.

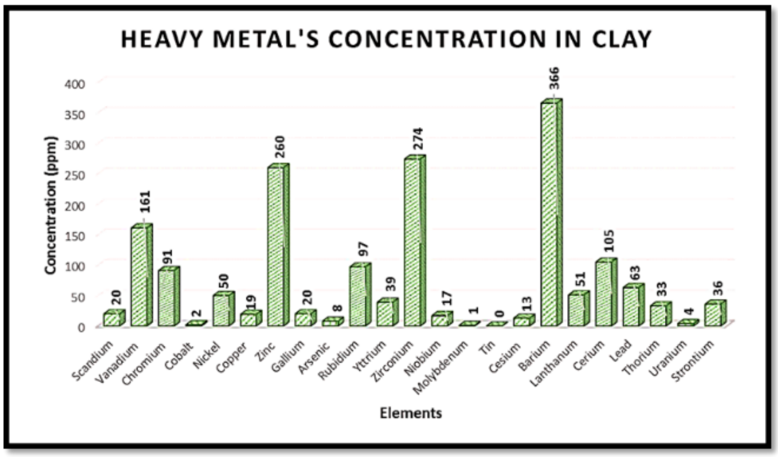


Figure 2. Concentration of heavy metals in clay versus percentage of concentration by using the *Standardless method*.

3.2. Physical and Mechanical Properties

3.2.1. Water Absorption. According to the graph, for 0% of sewage sludge that is control brick, the value of water absorption is 8%, followed by 1% of sewage sludge brick (SSB1%) with 10% of water absorption, 5% of sewage sludge brick (SSB5%) with 15% of water absorption, 10% of sewage sludge brick (SSB10%) with 17% of water absorption, 20% of sewage sludge brick (SSB20%) with 19% of water absorption and 30% of sewage sludge brick (SSB30%) with 21% of water absorption respectively. Based on the data recorded, it shows that the higher the amount of sewage sludge used in fired clay brick, more of water absorbed due to organic matter provided by sewage sludge in it. Furthermore, the increased of water absorption brick that incorporating with sludge affected by the increased formation of internal-voids due to burn-off of organic matter in the sludge [7]. Therefore, the sewage sludge bricks meet the load-bearing brick require according to the standard BS EN 722-21:2011 but not as engineering brick and damp proof brick.

3.2.2. Compressive Strength. From the results obtained, the graph showed compressive strength against the percentage of sewage sludge. The control brick which is containing 0% of sewage sludge had the highest of compressive strength with 21.6 MPa. Then the results obtained for different percentage of sewage sludge used showed that the value of compressive strength decreased over the amount of sewage sludge used. For SSB1%, the value of compressive strength decreases to 16.8 MPa followed by SSB5% with 12.3 MPa, SSB10% with 10.7 MPa and SSB20% with 5.8 MPa. While SSB30% decrease the strength to 3.1 MPa. However, the strength is still complying with a minimum standard BS EN 772-1:2011 of compressive strength which is 5 N/mm^2 for 1%, 5%, 10% and 20% of sewage sludge except for 30% of sewage sludge utilization. These indicate that the incorporation of sewage sludge in brick greatly affects the compressive strength value obtained [8]. The value of compressive strength reduced when more of sludge content used in the brick.

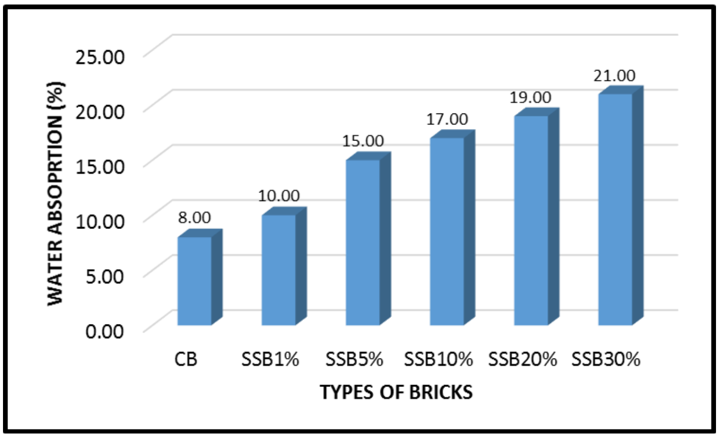


Figure 3. Water absorption versus percentage of sewage sludge.

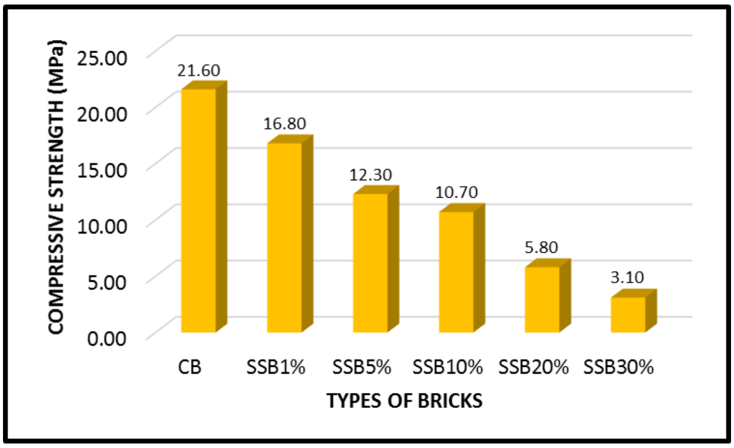


Figure 4. Compressive strength versus percentage of sewage sludge.

3.2.3. Density. According to the graph, the density of control bricks is 1888.51kg/m^3, while the density of fired clay bricks incorporating with different percentage of sludge is decreased when more amount of sewage sludge used. Incorporation of 1% sewage sludge (SSB1%) into fired clay brick, the value of density decreased to 1819.35kg/m^3, following by 5% of sewage sludge (SSB5%) with 1600.77kg/m^3, 10% of sewage sludge (SBB10%) with 1565.47kg/m^3, 20% of sewage sludge (SSB20%) with 1493.21kg/m^3 and 30% of sewage sludge (SSB30%) with 1450.69kg/m^3. Firing process is one of the reasons the density is decreased caused by the water loss due to high temperature applied [9]. Therefore, the amount of sewage sludge used in brick affecting the density of bricks which it becomes more porous and resulted to lightweight brick according to standard BS EN 722-13:2011.

3.2.4. Shrinkage. Based on the graph, five different percentage of sewage sludge that conducted in this study which are 1%, 5%, 10%, 20% and 30% were compared with control brick which is 0% of sewage sludge. The value of shrinkage of control brick is 1.63% while the other five different percentage of sewage sludge used are increased which are the shrinkage value is 2.05%, 2.51%, 3.18%, 4.20% and 5.50% respectively. A good quality brick will exhibit shrinkage less than 8%. Therefore, the amount of shrinkage occurs were influenced by the loss of water content in brick.

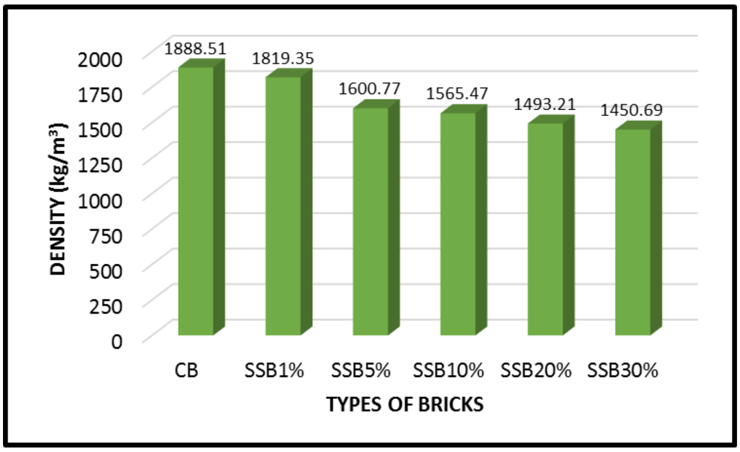


Figure 5. Density versus percentage of sewage sludge.

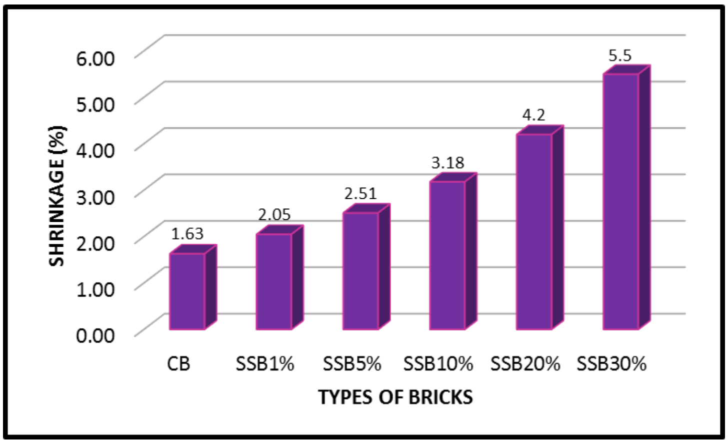


Figure 6. Shrinkage versus percentage of sewage sludge.

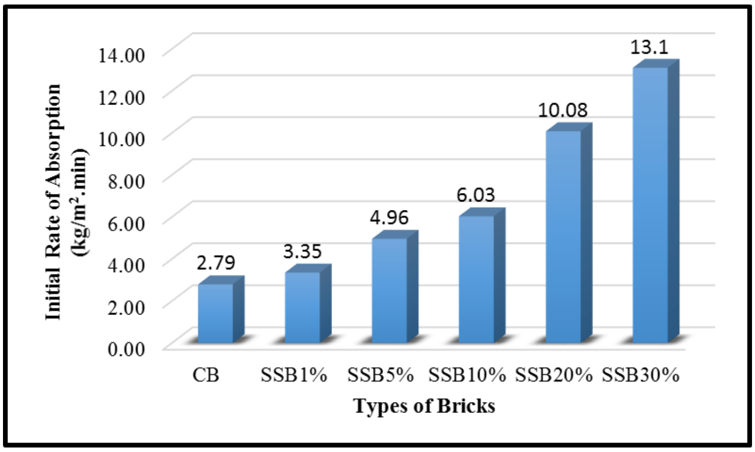
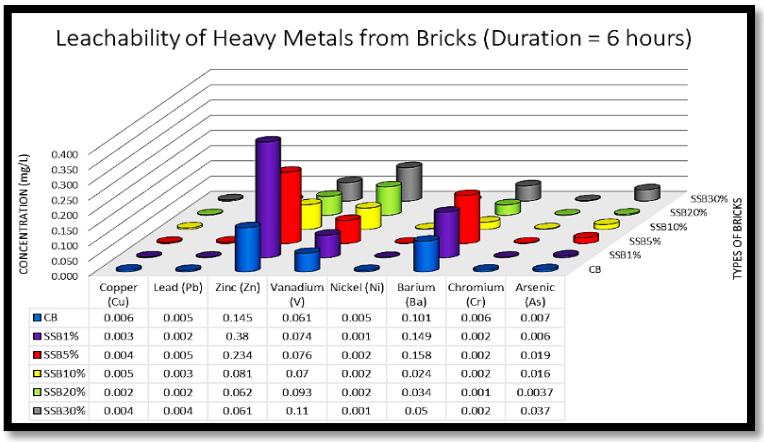


Figure 7. Initial rate of absorption versus percentage of sewage sludge.

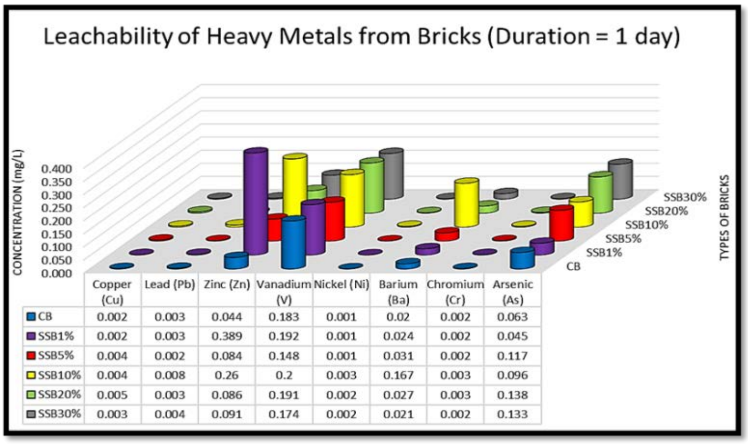
3.2.5. Initial Rate of Absorption (IRA). Based on the graph, five different percentage of sewage sludge that used in this study which are 1%, 5%, 10%, 20% and 30% were compared with control brick which is 0% of sewage sludge were conducted according to BS EN 722-11:2011 standard. The value of the initial rate of absorption of control brick is 2.79 kg/m^2.min while the other five different percentage of sewage sludge used are increased which are the shrinkage value is 3.35 kg/m^2.min, 4.96 kg/m^2.min, 6.03 kg/m^2.min, 10.08 kg/m^2.min and 13.1 kg/m^2.min respectively. In addition, the limit of the initial rate of absorption must less than 0.25 kg/m^2.min to considered as a low suction brick. However, sewage sludge incorporating in fired clay brick were regarded as high suction brick since the value of the initial rate of absorption is more than 1.50 kg/m^2.min. Furthermore, durability and quality of the bricks affect by the initial rate of absorption where lower value of IRA can lead to durable brick with higher resistance to the environment [11].

3.2.6. Leachability for Sewage Sludge Brick (Static Leachate Test). Based on the leachability of heavy metals that leaching out from bricks when immersed in leaching fluid according to the durations of time conducted, it shows that four types of elements that leaching out most were Zinc (Zn), Vanadium (V), Barium (Ba) and Arsenic (Ar) which Zinc (Zn) has recorded the highest value with 0.932 mg/L [10, 12].



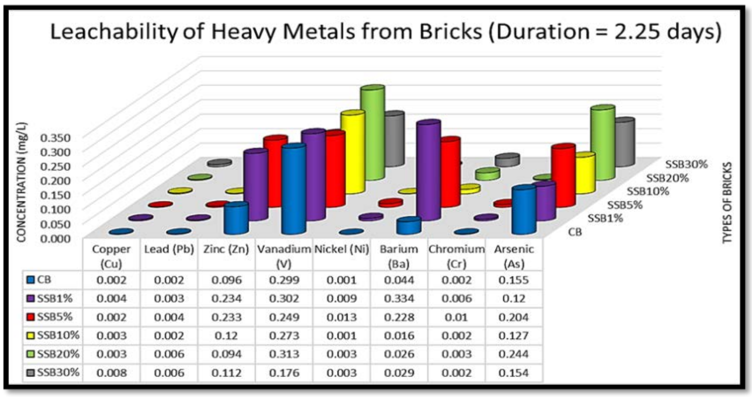
	Copper (Cu)	Lead (Pb)	Zinc (Zn)	Vanadium (V)	Nickel (Ni)	Barium (Ba)	Chromium (Cr)	Arsenic (As)
CB	0.006	0.005	0.145	0.061	0.005	0.101	0.006	0.007
SSB1%	0.003	0.002	0.38	0.074	0.001	0.149	0.002	0.006
SSB5%	0.004	0.005	0.234	0.076	0.002	0.158	0.002	0.019
SSB10%	0.005	0.003	0.081	0.07	0.002	0.024	0.002	0.016
SSB20%	0.002	0.002	0.062	0.093	0.002	0.034	0.001	0.0037
SSB30%	0.004	0.004	0.061	0.11	0.001	0.05	0.002	0.037

Figure 8. Leachability of heavy metals versus percentage of sewage sludge with 6-hours duration of immersed in leaching fluid.



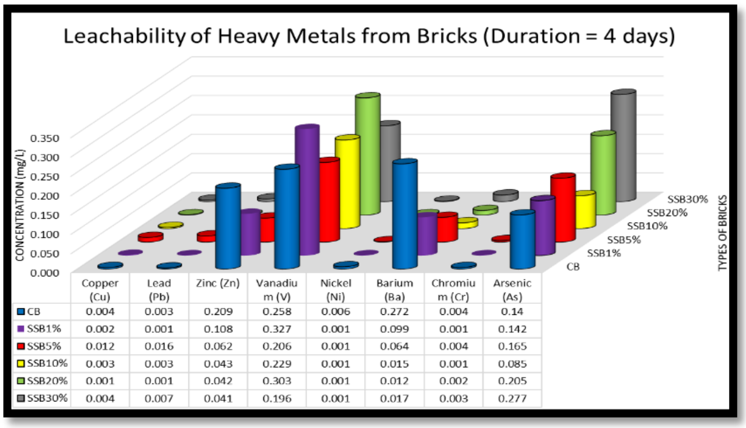
	Copper (Cu)	Lead (Pb)	Zinc (Zn)	Vanadium (V)	Nickel (Ni)	Barium (Ba)	Chromium (Cr)	Arsenic (As)
CB	0.002	0.003	0.044	0.183	0.001	0.02	0.002	0.063
SSB1%	0.002	0.003	0.389	0.192	0.001	0.024	0.002	0.045
SSB5%	0.004	0.002	0.084	0.148	0.001	0.031	0.002	0.117
SSB10%	0.004	0.008	0.26	0.2	0.003	0.167	0.003	0.096
SSB20%	0.005	0.003	0.086	0.191	0.002	0.027	0.003	0.138
SSB30%	0.003	0.004	0.091	0.174	0.002	0.021	0.002	0.133

Figure 9. Leachability of heavy metals versus percentage of sewage sludge with 1-day duration of immersed in leaching fluid.



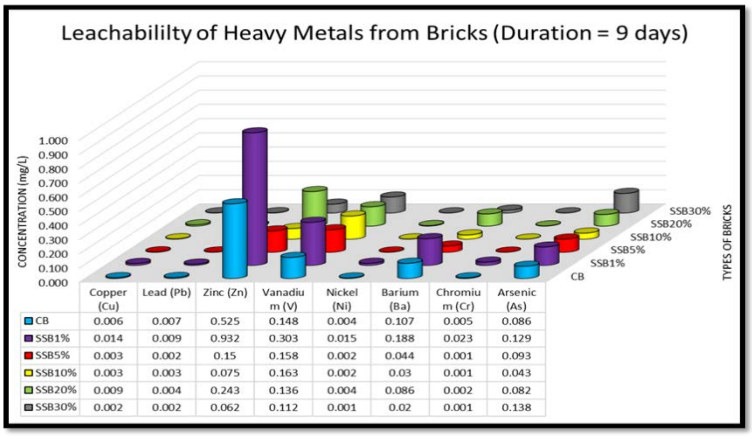
	Copper (Cu)	Lead (Pb)	Zinc (Zn)	Vanadium (V)	Nickel (Ni)	Barium (Ba)	Chromium (Cr)	Arsenic (As)
CB	0.002	0.002	0.096	0.299	0.001	0.044	0.002	0.155
SSB1%	0.004	0.003	0.234	0.302	0.009	0.334	0.006	0.12
SSB5%	0.002	0.004	0.233	0.249	0.013	0.228	0.01	0.204
SSB10%	0.003	0.002	0.12	0.273	0.001	0.016	0.002	0.127
SSB20%	0.003	0.006	0.094	0.313	0.003	0.026	0.003	0.244
SSB30%	0.008	0.006	0.112	0.176	0.003	0.029	0.002	0.154

Figure 10. Leachability of heavy metals versus percentage of sewage sludge with 2.25-days duration of immersed in leaching fluid.



	Copper (Cu)	Lead (Pb)	Zinc (Zn)	Vanadium (V)	Nickel (Ni)	Barium (Ba)	Chromium (Cr)	Arsenic (As)
CB	0.004	0.003	0.209	0.258	0.006	0.272	0.004	0.14
SSB1%	0.002	0.001	0.108	0.327	0.001	0.099	0.001	0.142
SSB5%	0.012	0.016	0.062	0.206	0.001	0.064	0.004	0.165
SSB10%	0.003	0.003	0.043	0.229	0.001	0.015	0.001	0.085
SSB20%	0.001	0.001	0.042	0.303	0.001	0.012	0.002	0.205
SSB30%	0.004	0.007	0.041	0.196	0.001	0.017	0.003	0.277

Figure 11. Leachability of heavy metals versus percentage of sewage sludge with 4-days duration of immersed in leaching fluid.



	Copper (Cu)	Lead (Pb)	Zinc (Zn)	Vanadium (V)	Nickel (Ni)	Barium (Ba)	Chromium (Cr)	Arsenic (As)
CB	0.006	0.007	0.525	0.148	0.004	0.107	0.005	0.086
SSB1%	0.014	0.009	0.932	0.303	0.015	0.188	0.023	0.129
SSB5%	0.003	0.002	0.15	0.158	0.002	0.044	0.001	0.093
SSB10%	0.003	0.003	0.075	0.163	0.002	0.03	0.001	0.043
SSB20%	0.009	0.004	0.243	0.136	0.004	0.086	0.002	0.082
SSB30%	0.002	0.002	0.062	0.112	0.001	0.02	0.001	0.138

Figure 12. Leachability of heavy metals versus percentage of sewage sludge with 9-days duration of immersed in leaching fluid.

IOP Conf. Series: Materials Science and Engineering **374** (2018) 012096 doi:10.1088/1757-899X/374/1/012096

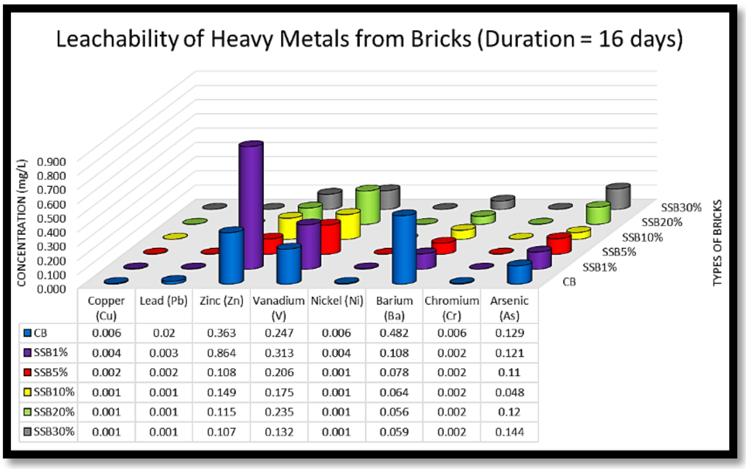


Figure 13. Leachability of heavy metals versus percentage of sewage sludge with 16-days duration of immersed in leaching fluid.

While the other elements that were found leaching out together were also including Copper (Cu), Lead (Pb), Nickel (Ni) and Chromium (Cr) with the least amount of leachability concentration of heavy metals from bricks which were less than 0.050 mg/L. However, the leachability of heavy metals that leach out from all bricks for 6-hours, 1-day and 2.25-days, 4-days, 9-days and 16-days duration of immersed in leaching fluid conducted still comply with the standard where the value of concentration does not exceed with the value provided by US Environment Protection Agency (1997).

4. Conclusions

As a conclusion incorporating sewage sludge in fired clay brick is an alternative to dispose of sewage sludge. This is because the value of physical and mechanical properties that have been conducted still comply with the limit that provided in each standard for the testing. Even the value slightly different with the normal fired clay brick, the sewage sludge incorporating in fired clay brick able to reduce the amount to be dumped into a landfill and also can provide a good low-cost material in the production of fired clay brick. Therefore, the utilization of sewage sludge incorporating in fired clay brick that suitable to be used as a second raw material which was 1%, 5%, 10% and 20% since the percentages used to comply with all the physical and mechanical properties limit. While for the 30% of sewage sludge used does not meet the requirement of the standard because the value obtained was less than 5 N/mm2. Apart from that, leachability of heavy metals from sewage sludge incorporating in fired clay brick compared to normal fired clay brick also shown that it has slightly different value. Furthermore, the value obtained according to all duration of bricks immersed in leaching fluid shows that the value does not exceed the value provided in USEPA standard for each of the elements of heavy metals found. However, heavy metals that leaching out from sewage sludge incorporating in fired clay brick are not harmful to the environment and also to human health.

5. References

[1] Usman K, Khan S, Ghulam S, Khan M U, Khan N, Khan M A and Khalil S K 2012 *American Journal of Plant Sciences* **3** 1708-21
[2] Werle S and Wilk R K 2010 *Renewable Energy* **35(9)**1914-19
[3] Shakir A A 2013 *Development of Brick from Waste Material: A Review Paper* **7(8)** 812-818
[4] Gurjar and Tyagi 2017 *Sludge Management* (Taylor and Francis Group. London, United Kingdom)
[5] Ibrahim W M W, Hussin K, Abdullah M M A B, Kadir A A, Deraman and Sandu A V 2017 *Revista De Chimie* ***68(9)*** 1978-82

[6] Kadir A A, Hassan M I H, and Mohamad S K H S 2015 *Appl. Mech. Mater* **133** 012036
[7] Liew A G, Idris A, Wong C H K, Samad A A, Noor M J M M and Baki A M 2004 Waste Management and Research **4** 226-33
[8] Pillai A G and Chandrakaran S 2017 Utilization of Sludge in the Manufacturing of Fired Clay Bricks *International Conference on Geotechniques for Infrastructure Projects. India* 679–685
[9] Md Nor M A, Hamed A S A, Ali F H and Ong K K 2015 Jurnal Teknologi, Sciences & Engineering **3** 1708-21
[10] Benlamoudi A, Kadir A A, Titu M A Abdullah M M A B Sandu A V 2017 *Revista de Chimie* **68(8)** 1908-13
[11] Ukwatta A, Mohajerani A, Eshtiagi N and Setunge S 2016 Journal of Cleaner Production **119** 76-85
[12] Gruszka K, Nabialek M, Szota M, Vizureanu P, Abdullah M M A, Bloch K, Sandu A V 2017 *Revista de Chimie* **68(2)** 265-268

Acknowledgments
The results presented in this paper are part of an ongoing postgraduate research. This research was financially supported by Fundamental Research Grant Scheme (FRGS) Vot 1527 under Ministry of Higher Education of Malaysia. Special thanks to Office for Research, Innovation, Commercialization and Consultancy Management (ORICC) from University Tun Hussein Onn Malaysia.