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Incorporation of Sludge from Wastewater Treatment Plant in Fired Clay Brick: Properties and Leaching Analysis

Nurul Salhana Abdul Salim[1], Aeslina Abdul Kadir[1*], Mohd Hafizul Fadzli Zaidi[1] and Mohamad Asyraf Kamarudin[1]

[1]*Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat Johor, Malaysia.*

ABSTRACT

A large quantity of sludge is generated each year from wastewater treatment plants in Malaysia. Disposal of sludge at sanitary landfill is the common practice. This is impractical because of the high cost of transportation and because it depletes the capacity of the landfill. Moreover, heavy metals in sewage sludge will produce leaching and pollute the environment. Reuse of the sludge could be an alternative to the current disposal method. This study investigated the reusability of sewage sludge as fired clay brick. Different series of sludge and clay proportioning ratios were studied, which exclusively involved the addition of sludge with ratios of 1%, 5%, 10%, 20% and 30% of the total weight of sludge-clay mixture. X-ray Fluorescence (XRF) analysis were used to characterize clay and sewage sludge. The physical and mechanical properties test was conducted to all bricks production. Tank Leaching Test according to NEN7345 method was conducted to define heavy metals leachability in bricks. The leaching result from incorporation of fired clay bricks with sewage sludge fulfilled the requirement limits of USEPA for bricks. As a conclusion, the utilization of sewage sludge into fired clay bricks can reduce the disposal to landfill and becoming an alternative disposal method.

Keywords: Brick Properties, Heavy Metals, Leachability, Sewage Sludge Brick, Waste Management.

1. INTRODUCTION

Sewage sludge must be treated or stabilized to be safe for use or dispose. Worldwide, sewage sludge is disposed by different methods. Commonly, it will disposed in landfills and highly difficult to find suitable sites as urbanization rapidly change [1]. Hence, heavy metals produce leaching into groundwater, surface water and soils which resulting hazardous problems to human and also environment [2]. Other method is incineration which reduces only the volume of sewage sludge but the remaining ash would still needed to be dispose in landfills [3]. Therefore, there is a growing need to explore new fields of sludge disposal where one of the areas is to use sewage sludge as an additive for the production of fired clay bricks.

Malaysia produces more than 400,000 million litres per day (MLD) of treated water from over 450 of wastewater treatment plants (WWTP) which generated large amount of sludge simultaneously. In 2013, 491,902.87 metric tons of wastewater treatment sludge (WTS) estimated to be produced and managed [4]. As a result, more land need to provide for landfilling which is the common method of disposing sewage sludge. The sewage sludge which contain various heavy metals will leaching into the ground where groundwater and soil will be contaminated [2]. For a long term application, this disposal method will cause environmental effect. Hence, alternative method which will reduce the cost and amount of sewage sludge to be disposed is needed.

* Corresponding Author: *aeslina@uthm.edu.my*

There are several studies have been carried out to use sewage sludge in brick, aggregate, cement, and ceramic making. The use of sewage sludge in brick manufacture has been highly encouraged as the mineral composition of clay brick and sludge is similar but less attention on leaching is being conducted. Therefore, in this study the potential of utilizing sludge will be investigated in term of properties as well as leachability.

2. MATERIAL AND METHODS

Table 1 Mix ratio of brick production

Sample	Mix Ratio	
	Clay (Kg)	Sludge (kg)
Control Brick 0% (CB)	3.00	0.00
Sewage Sludge Brick 1% (SB1%)	2.97	0.03
Sewage Sludge Brick 5% (SB5%)	2.85	0.15
Sewage Sludge Brick 10% (SB10%)	2.70	0.30
Sewage Sludge Brick 20% (SB20%)	2.40	0.60
Sewage Sludge Brick 30% (SB30%)	2.10	0.90

The disposed sludge were collected from Water Treatment Plant and the clay from a factory in Johor, Malaysia. Raw clay and sewage sludge was dried for 24 hours with 105°C of temperature in the oven before crushing process. Then, X-ray Fluorescence (XRF) test was conducted on these both raw material as to obtain the chemical composition and concentration of heavy metals. The samples were prepared by incorporating 0%, 1%, 5%, 10%, 20% and 30% sludge into fired clay brick. The production of bricks was dried for 24 hours with 105°C of temperature in the oven and completely fired with 1050°C for 24 hours in the furnace. Physical and mechanical properties was conducted for all bricks production as compressive strength, water absorption, shrinkage, density and also the initial rate of absorption. Then, the leachability of heavy metals from each samples were measured by using Tank Leaching Test according to NEN 7345 method with each of sample was soaked into a polyethylene container and completely submerged with the fluid that filled with acidic water with HNO3 at pH=4. The leachate was collected, removed and replaced with fresh extractions after 6hours, 1day, 1day 6hours, 4days, 9days, 16days, 36days and 64days as per NEN 7345. Triplicate samples from all the leachates were produced and analysed for heavy metals using Inductive Coupled Plasma Mass Spectrophotometer (ICPMS).

3. RESULTS AND DISCUSSION

3.1 X-ray Fluorescence (XRF)

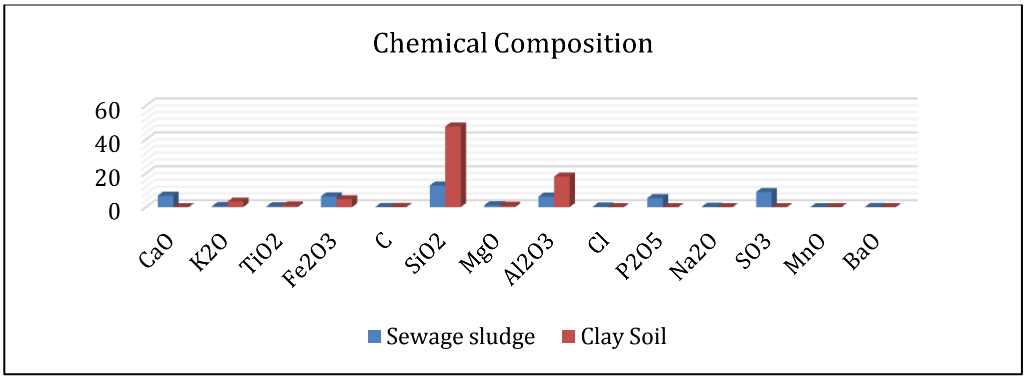


Figure 1. Chemical Composition for sewage sludge and clay soil.

Figure 1 shows the chemical composition that found in sewage sludge and clay. Chemical composition that found in sewage sludge were Calcium oxide (CaO), Potassium oxide (K2O), Titanium dioxide (TiO_2), Ferric oxide (Fe_2O_3), Carbon (C), Silicon dioxide (SiO_2), Magnesium oxide (MgO), Aluminium oxide (Al_2O_3), Chlorine (Cl), Phosphorus pentoxide (P_2O_5), Sulfur trioxide (SO_3), Manganese oxide (MnO) and Barium oxide (BaO). From the result, it show that Calcium oxide (CaO) with 6.79% just obtained in sludge but not available in clay soil. Then, 3.34% for clay and 0.66% for sludge of Potassium oxide (K_2O) while Titanium dioxide (TiO_2) obtained by 0.97% for clay and 0.50% for sludge. Ferric oxide (Fe_2O_3) result for sludge was 6.41% and for clay is 4.67% respectively. For Magnesium oxide (MgO), the data shows 1.09% for sludge and 0.87% for clay while Aluminium oxide (Al_2O_3) give 6.26% and 18% for sludge and clay. The highest chemical composition available in both sludge and clay was Silicon dioxide (SiO_2) with 12.8% and 47.6%. Where for sludge and clay had same value of Carbon (C) which is 0.10%. Then, the composition which available on sludge only was Chlorine (Cl) with 0.38%, Phosphorus pentoxide (P_2O_5) with 5.36%, Sodium oxide (Na_2O) with 0.27%, Sulfur trioxide (SO_3) with 8.98% and Barium oxide (BaO) with 0.14% respectively. The lowest percent obtained for Manganese oxide (MnO) in sludge is 0.06% and clay is 0.04%.

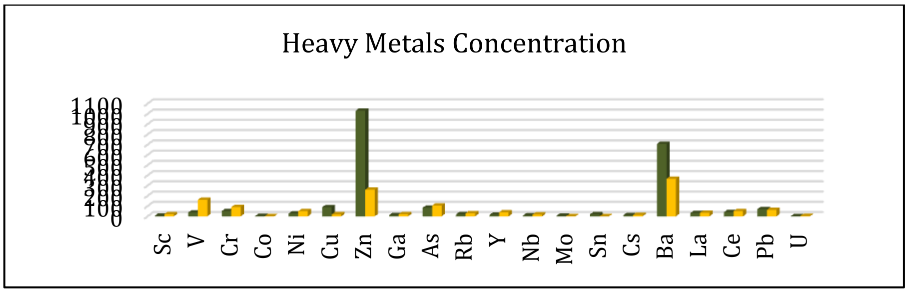


Figure 2. Heavy Metals Concentration for sewage sludge and clay soil.

Meanwhile, Figure 2 shows concentration of heavy metals in raw clay soil and sewage sludge from XRF result. It shows that clay soil contain 20 ppm while sludge have 5 ppm of Scandium (Sc). For Vanadium (V) shows lower value in sludge with 37 ppm but higher value in clay with 161 ppm. Then, the Chromium (Cr) indicate 51 ppm for sludge where 91 ppm for clay. Meanwhile, Zinc (Zn) concentration for sludge indicate that 1030 ppm which is the highest from other heavy metals where 260 ppm for clay. From the overall, the highest concentration obtained for clay soil is Barium (Ba) with 366 ppm, Zinc (Zn) with 260 ppm, Vanadium (V) with 161 ppm and Arsenic (As) with 105 ppm. Meanwhile, the sludge obtained higher concentration on Zinc (Zn) with 1030 ppm, Barium with 707 ppm, Copper (Cu) with 89 ppm and Arsenic (As) with 83 ppm respectively while the other elements were recorded with less than 100 ppm value of concentration.

3.2 Physical and Mechanical Properties

3.2.1 Water Absorption

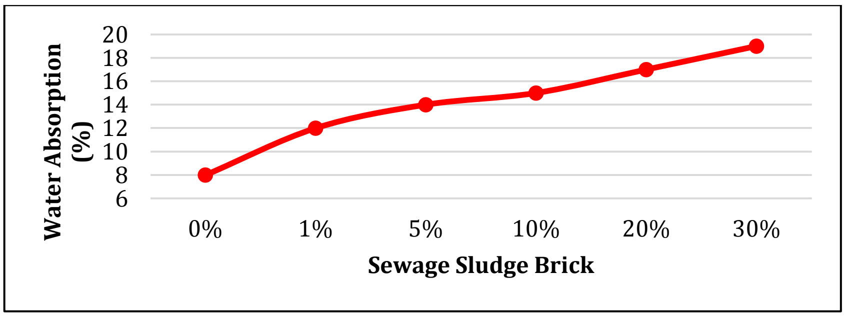


Figure 3. Water absorption of bricks.

Figure 3 shows the result of water absorption of bricks. According to the result, the data obtained for 0% of sludge which is control brick (CB) had 8% of water absorption. For 1% of sludge brick the value is 12% which higher than CB. Then, SB5% sample obtained 14% of water absorption while 15% for specimen with 10 percent sludge. Sludge brick for 20% data shows 17% of water absorb where for SB30% obtained 19% which is the highest from other sample. These show that percent of water absorption increase as the amount of sludge increase where sludge have more pores than clay [5]. The minimum percentage of absorption for engineering brick is below and equal to 7% according to BS: EN 772-1:2011. These show that the sewage brick sample data exceed the minimum requirement of engineering brick but still meet the load-bearing bricks requirement.

3.2.2 Compressive Strength

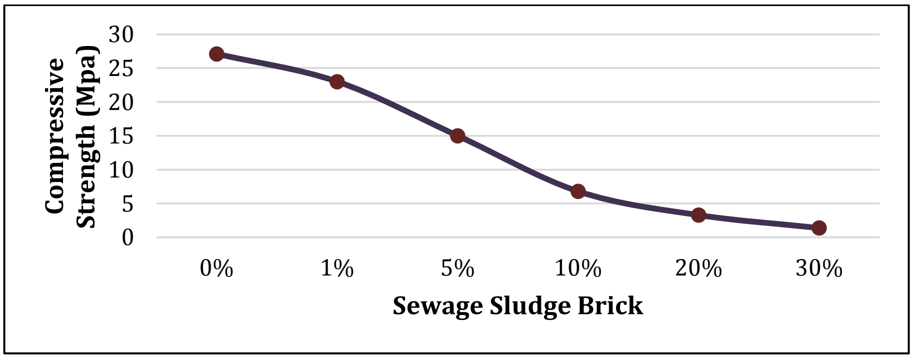


Figure 4. Compressive strength of bricks.

From the results obtained, Figure 4 showed compressive strength against the percentage of sewage sludge. The control brick (CB) had the highest strength value from other sample with 21.6MPa. Followed by sludge brick (SB1%) obtained with 17.6MPa, 13.1MPa for SB 5%. The data with 11.9MPa shown for SB 10% and 6.2MPa for SB 20%. For brick with 30% sludge shown the lowest compressive strength with 3.6MPa. Therefore, the strength of for 1%, 5%, 10% and 20% of sewage sludge is still complying with a minimum standard BS EN 772-1:2011 of compressive strength which is 5N/mm^2 except for 30% of sewage sludge utilization. These indicate that the percentage of sludge in a clay brick highly affects the compressive strength obtained. This result also supported by [6] that obtained the same trend of compressive strength result.

3.2.3 Density

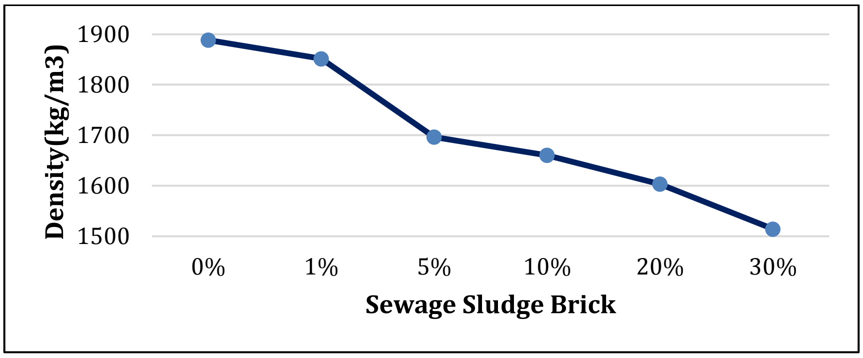


Figure 5. Density of bricks.

According to the Figure 5, the density of control bricks is 1888.51kg/m^3 which is the highest. The result obtained for SB1% is slightly lower from control brick which is 1851.41kg/m^3. The density for 5% of sludge brick is 1696.47kg/m^3 where 1660.37kg/m^3 for SB10%. Then, for brick with 20% sludge had density value of 1603.31kg/m^3 while for brick with 30% of sludge mixture obtained 1514.02 kg/m^3 which is the lowest from other sample. The density is decreased caused by the water loss due to high temperature applied in firing process [2]. It is also related to the amount of sludge in brick, the more sludge contained in brick, the larger size of pore in brick will create during firing hence resulted a light density of brick. The percentage of sludge in 20% and 30% of fire clay brick shows a lightweight brick where the density is below 1650 kg/m^3. Meanwhile for other percent is class in dense brick according to BS: EN 772-1:2011.

3.2.4 Shrinkage

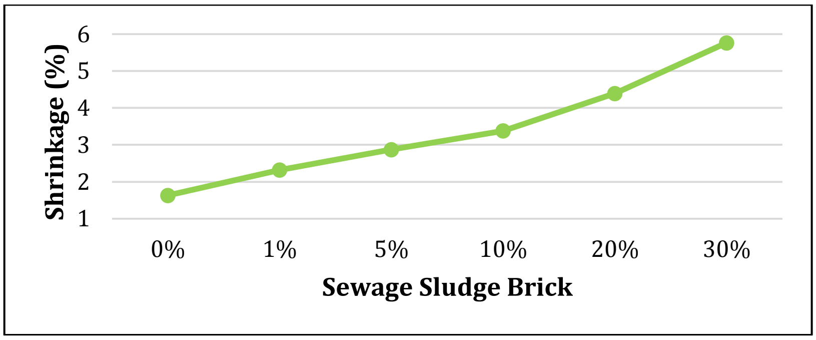


Figure 6. Shrinkage of bricks.

Based on the Figure 6, for control brick, the shrinkage obtained is 1.63% which is the lowest while 2.32% for SB1%. Then, 2.87% for mixes specimen with 5% and brick with 10% sludge show 3.38% of shrinkage. The brick mixes with 20% sludge obtained 4.39% where 5.76% of shrink for SB30%. These show that shrinkage is affect by percentage of sludge. From the result shows that the shrinkage increase with the increasing of sludge proportion. This is also supported by [7] that stated shrinkage of the bricks depends on the properties of the components, the proportion of the components, mixing manner, the amount of moisture and dry environment.

3.2.5 Initial Rate of Absorption (IRA)

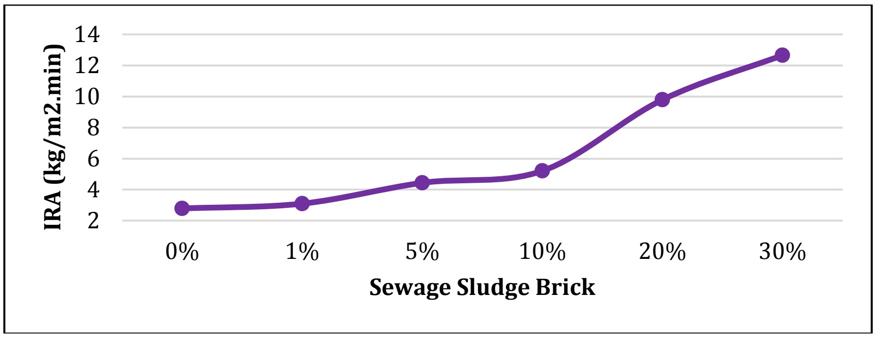


Figure 7. IRA of bricks.

Figure 7 shows the result of initial rate of absorption. From the result, it can be seen that all the brick mixes obtained higher IRA than control brick which is 2.79kg/m^2.min. For SB1% the value is 3.1 kg/m^2.min while for mixes with 5% sludge obtained 4.44 kg/m^2.min. Then, for the sample with 10% of sludge mixes has 5.21 kg/m^2.min of IRA where 9.79 kg/m^2.min for SB20%. For brick mixes with 30% has highest IRA value which is 12.65 kg/m^2.min. From the result shows that the IRA result increase when the sewage sludge amount is increase compared to the control brick. This is because the increasing in pore size increase the rate of absorption [8]. Water absorption affects the durability of bricks, thus the less water infiltrates into brick, and the more durable is the brick [9].

3.3 Heavy Metals Leachability

According to the result obtained, leachability of heavy metals that leaching out from brick were Copper (Cu), Lead (Pb), Zinc (Zn), Nickel (Ni), Vanadium (V), Barium (Ba) Chromium (Cr) and Arsenic (As). Furthermore, the result will be discussed accordingly.

3.3.1 Copper (Cu)

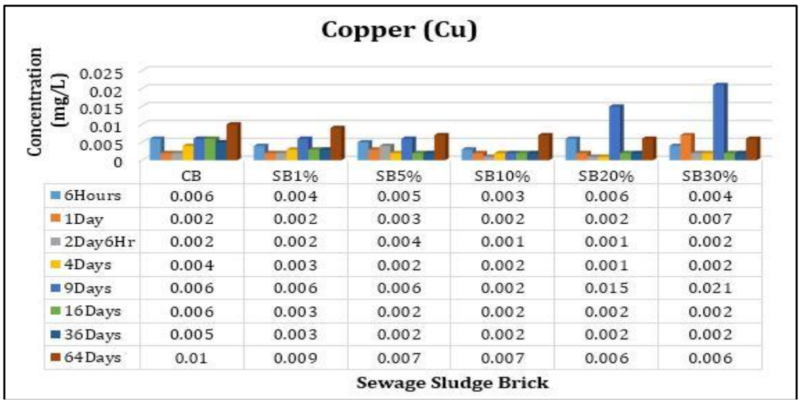


Figure 8. Concentrations of Copper (Cu).

Figure 8 shows the result of Copper (Cu) for each bricks and duration of tank leaching test of bricks. From the result, the concentration of Copper for control brick (CB), SB1% and SB5% is the highest with 0.01 mg/L, 0.009 mg/L and 0.007 mg/L respectively compared to the lowest value with 0.002 mg/L where the difference is 67%. For SB10%, the concentration decrease uniformly with 0.003 mg/L at 6 hours, 0.002 mg/L at 1 days and 0.001 mg/L at 2 days 6 hour. Then, increase and constant until 36 days with 0.002 mg/L and rapidly increased at 64 days with 0.007 mg/L. The result obtained for SB20% shows at 9 days is the highest value with 0.015 mg/L where the difference is 60% and 83% with 6 hour and 1 days at 0.006 mg/L and 0.002 mg/L. For SB30%, the result for 9 days is the highest with 0.021 mg/L compare to 6 hours and 1 days with 0.004 mg/L and 0.007 mg/L where the difference is 43% and 67%. The average concentration for Copper is about 0.004 mg/L. However according to USEPA (U.S Environmental Protection Agency), the concentration is below the guideline which is 100 mg/L.

3.3.2 Lead (Pb)

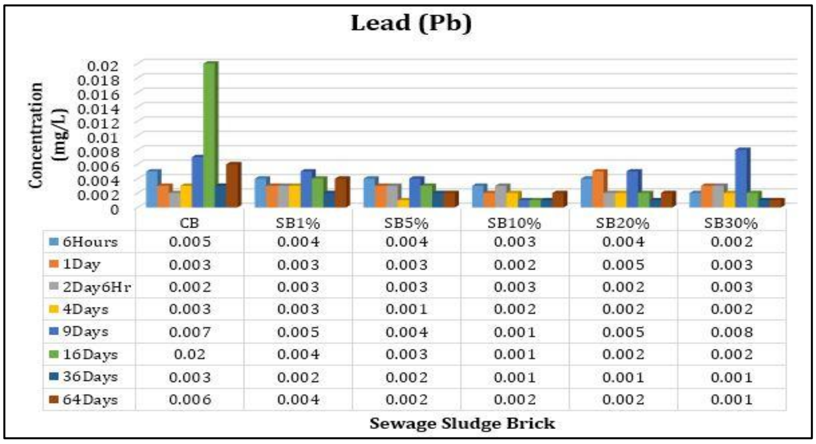
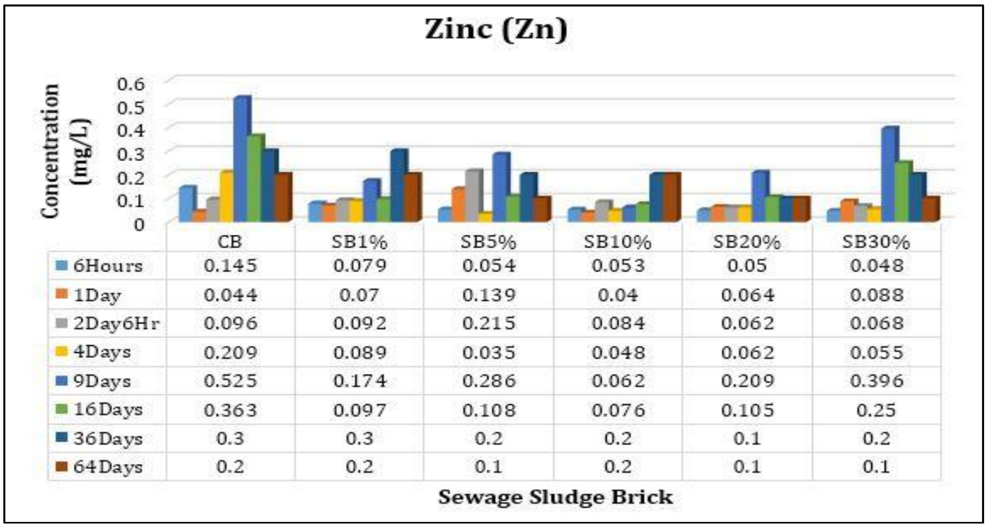


Figure 9. Concentrations of Lead (Pb).

Figure 9 shows the result of Lead concentration with all duration and percentage of sludge. For CB, it shows that at duration 16 day the concentration is 0.020 mg/L which the highest where the lowest at 2 day 6 hour at 0.002mg/L with the difference of 90%. Then, for SB1% and SB5% which had same concentration at 6 hours with 0.004 mg/L and 0.003 mg/L at both 1 days and 2 days 6 hour duration where the difference is 25%. The highest Lead (Pb) leached occurs on duration of 9 days with 0.005 mg/L. For SB10%, it shows 0.003 mg/L at duration 6 hours and 2 days 6 hour while 0.002 mg/L at 1 days which 33% lower from both duration. Next, for SB20% at 6 hours the value is 0.004 mg/L, 0.005 mg/L at 1 days and 9 days which the highest from other duration and 0.002 mg/L at 2 days 6 hour, 4 days and 16 days. Meanwhile, for SB30% the highest concentration is 0.008 mg/L at 9 days while 0.003 mg/L at both 1 days and 2 days 6 hour. The average concentration for Lead is about 0.004 mg/L. The result obtained is lower from USEPA requirement of concentration which at 5 mg/L with average difference of 99%.

3.3.3 Zinc (Zn)

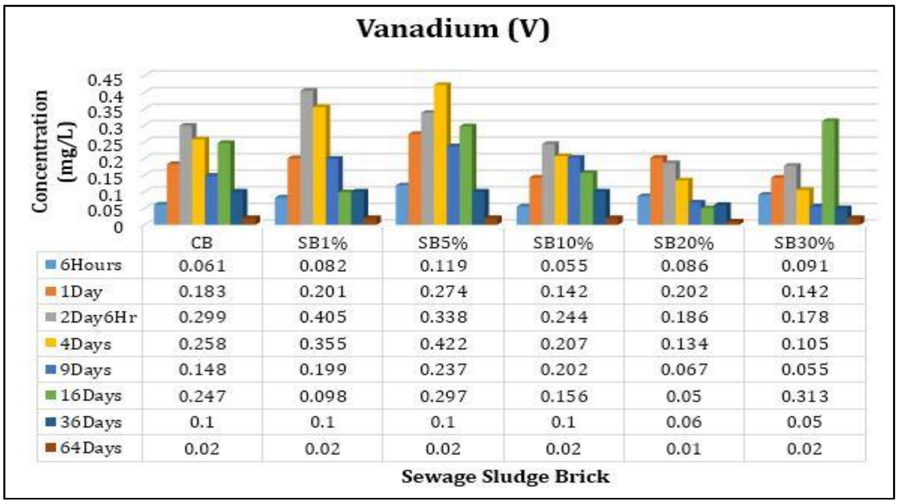


	CB	SB1%	SB5%	SB10%	SB20%	SB30%
6Hours	0.145	0.079	0.054	0.053	0.05	0.048
1Day	0.044	0.07	0.139	0.04	0.064	0.088
2Day6Hr	0.096	0.092	0.215	0.084	0.062	0.068
4Days	0.209	0.089	0.035	0.048	0.062	0.055
9Days	0.525	0.174	0.286	0.062	0.209	0.396
16Days	0.363	0.097	0.108	0.076	0.105	0.25
36Days	0.3	0.3	0.2	0.2	0.1	0.2
64Days	0.2	0.2	0.1	0.2	0.1	0.1

Figure 10. Concentrations of Zinc (Zn).

Figure 10 shows the result for concentration of Zinc that leached in sludge brick and control brick. It can be seen that for CB at 9 days is the highest concentration with 0.525 mg/L then followed by 0.363 mg/L at 16 days and 0.209 mg/L at 4 days. For SB1%, the concentration is 0.174 mg/L at 9 days which the higher from other duration. Then, for SB5% the result is increase from 0.054 mg/L at 6 hours to 0.215 mg/L at 2 day 6 hours then drop to 0.035 mg/L at 4 days but increase highly at 9 days with 0.286 mg/L. Meanwhile, for SB10% the highest result is 0.200mg/L at 36 days and 64 days where the lowest is 0.040 mg/L at 1 days. For SB20%, the result at 6 hours is 0.05 mg/L and decrease by 51.5% at 1 day period with 0.0064 mg/L and 2 days 6 hour with 0.062 mg/L. Then, increase with the highest with 0.209 mg/L at 9 days and decrease to 0.105 mg/L at 16 days and 0.1 mg/L at 36 days and 64 days. Next, for SB30% the result is not more than 0.100 mg/L for all duration except at 9 days the highest value is 0.396 mg/L. The data obtained for Zinc, Zn is compare to USEPA where the result is below from 500 mg/L which is allowed.

3.3.4 Vanadium (V)

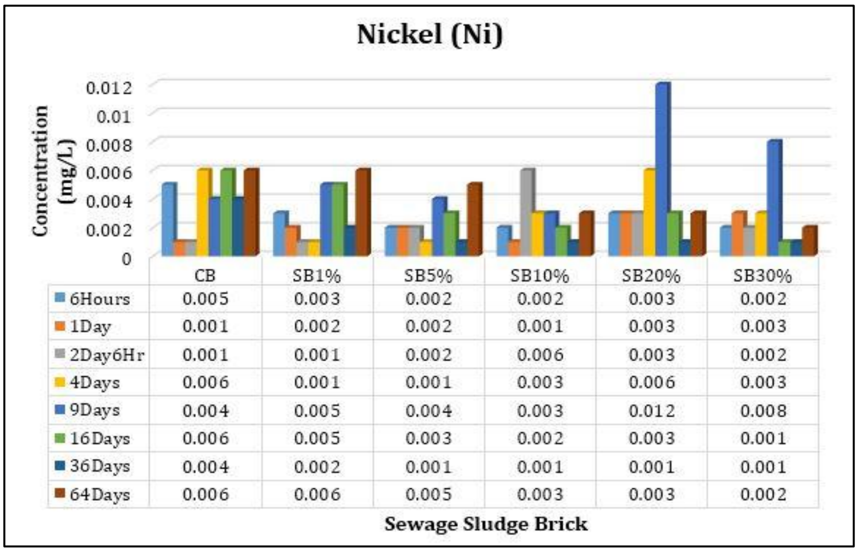


	CB	SB1%	SB5%	SB10%	SB20%	SB30%
6Hours	0.061	0.082	0.119	0.055	0.086	0.091
1Day	0.183	0.201	0.274	0.142	0.202	0.142
2Day6Hr	0.299	0.405	0.338	0.244	0.186	0.178
4Days	0.258	0.355	0.422	0.207	0.134	0.105
9Days	0.148	0.199	0.237	0.202	0.067	0.055
16Days	0.247	0.098	0.297	0.156	0.05	0.313
36Days	0.1	0.1	0.1	0.1	0.06	0.05
64Days	0.02	0.02	0.02	0.02	0.01	0.02

Figure 11. Concentrations of Vanadium (V).

Figure 11 shown the result concentration of Vanadium with the testing duration and percentage of sludge in brick. The CB sample obtained 0.061 mg/L at 6 hours then increase by 67% at 1 days with 0.183 mg/L and increase by 39% at 2 days 6 hour with 0.299 mg/L which the highest. For SB1%, the data obtained at 6 hours is 0.082 mg/L, 0.201 mg/L at 1 days and increase by 50% at 2 days 6 hour with 0.405 mg/L but decrease gradually until 76% at 16 days with 0.098 mg/L. Then, for SB5% also shows an increasing concentration from 0.119 mg/L at 6 hours to 0.274 mg/L at 1 days then with increasing of 19% at 2 days 6 hour is 0.338 mg/L and the highest at 4 days with 0.422 mg/L and decrease until 0.02 mg/L at 64 days. The sample for SB10% shows 0.055 mg/L at 6 hours then increase by 61% at 1 days with 0.142 mg/L and again by 42% at 2 days 6 hour with 0.244 mg/L. But then decrease until 0.156 mg/L at 9 days and increase again on 16 days with 0.238 mg/L. Moreover, for SB20% indicates that a concentration of 0.086 mg/L at 6 hours then increase at 1 days with 0.202 mg/L by 57% and decrease by 8% at 2 days 6 hour with 0.186 mg/L. Lastly, for SB30% it shows a bell shape value but then at 16 days the highest concentration is 0.313 mg/L.

3.3.5 Nickel (Ni)

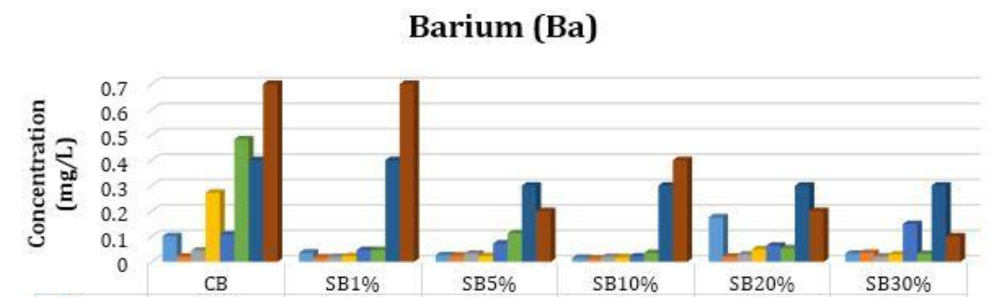


	CB	SB1%	SB5%	SB10%	SB20%	SB30%
6Hours	0.005	0.003	0.002	0.002	0.003	0.002
1Day	0.001	0.002	0.002	0.001	0.003	0.003
2Day6Hr	0.001	0.001	0.002	0.006	0.003	0.002
4Days	0.006	0.001	0.001	0.003	0.006	0.003
9Days	0.004	0.005	0.004	0.003	0.012	0.008
16Days	0.006	0.005	0.003	0.002	0.003	0.001
36Days	0.004	0.002	0.001	0.001	0.001	0.001
64Days	0.006	0.006	0.005	0.003	0.003	0.002

Figure 12. Concentrations of Nickel (Ni).

Figure 12 below indicate the concentration of Nickel (Ni) which had become leachate from acid solvent. For CB, the highest is at 4 days, 6 days and 64 days where the concentration is 0.006 mg/L while for both period of 1 days and 2 days 6 hour the result is same with 0.001 mg/L except for 6 hours with 0.005 mg/L. The SB1% sample obtained a decreasing value from 0.003 mg/L at 6 hours to 0.002 mg/L at 1 days and then to 0.001 mg/L at 2 days 6 hour and 4 days but increase to 0.005mg/L until 16 days but rapidly increase at 64 days. Then, for SB5% shows a uniform data where at 6 hours, 1 days and 2 days 6 hour the concentration is 0.002 mg/L but highest at 64 days days with 0.004 mg/L. SB10% indicate a 0.002 mg/L concentration at 6 hours then decrease by 50% at 1 days with 0.001 mg/L and highly increase to 0.006 mg/L at 2 days 6 hour but decrease until 0.001 mg/L at 36 days. For SB20%, the data is remained same through the period where the concentration is 0.003 mg/L then increase with the highest at 9 days with 0.012 mg/L. Next, for SB30% the result is highest at 9 days with 0.008 mg/L. From USEPA the allowed concentration for Nickel is below 1.3 mg/L where it shows that the result of concentration for each sample along the period is lower than the limit requirement.

3.3.6 Barium (Ba)



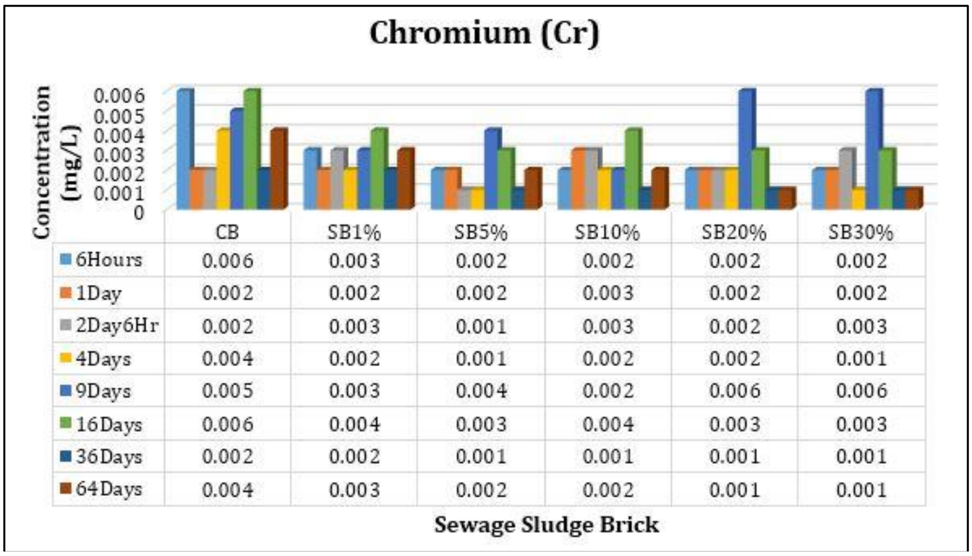
	CB	SB1%	SB5%	SB10%	SB20%	SB30%
6Hours	0.101	0.036	0.026	0.016	0.175	0.032
1Day	0.02	0.017	0.024	0.013	0.02	0.035
2Day6Hr	0.044	0.019	0.032	0.019	0.029	0.021
4Days	0.272	0.022	0.023	0.018	0.049	0.029
9Days	0.107	0.046	0.072	0.021	0.064	0.149
16Days	0.482	0.046	0.112	0.035	0.053	0.031
36Days	0.4	0.4	0.3	0.3	0.3	0.3
64Days	0.7	0.7	0.2	0.4	0.2	0.1

Sewage Sludge Brick

Figure 13. Concentrations of Barium (Ba).

Figure 13 shows the result of concentration of Barium (Ba) for all duration and percentage of sludge in fired clay brick. The CB sample shows a high concentration at 6 hours period with 0.101 mg/L, at 4 days with 0.272 mg/L, 16 days at 0.482 mg/L and highest at 64 days at 0.7 mg/L. Then, for SB1% the value obtained is minimal from 0.017 mg/L at 1 day to the higher at 9 and 16 days with 0.046 mg/L and steadily increased until the highest result at 64 days with 0.7 mg/L. For SB5%, the value shows an average minimal concentration range from 0.023 mg/L to 0.072 mg/L but achieve a high concentration until 64 days with 0.2 mg/L. Then, for SB10% the concentration is lower from duration of 6 hours until 9 days with range from 0.013 mg/L to 0.021 mg/L and gradually increase until 64 days. SB20% has the highest concentration at 36 days duration with 0.3 mg/L. Lastly, as for SB30% the data is average minimal about 0.030 mg/L but at 9 days, 36 days and 64 days the concentration is high with 0.149 mg/L, 0.3 mg/L and 0.1 mg/L respectively. The result obtained for Barium is still below USEPA at 100 mg/L.

3.3.7 Chromium (Cr)

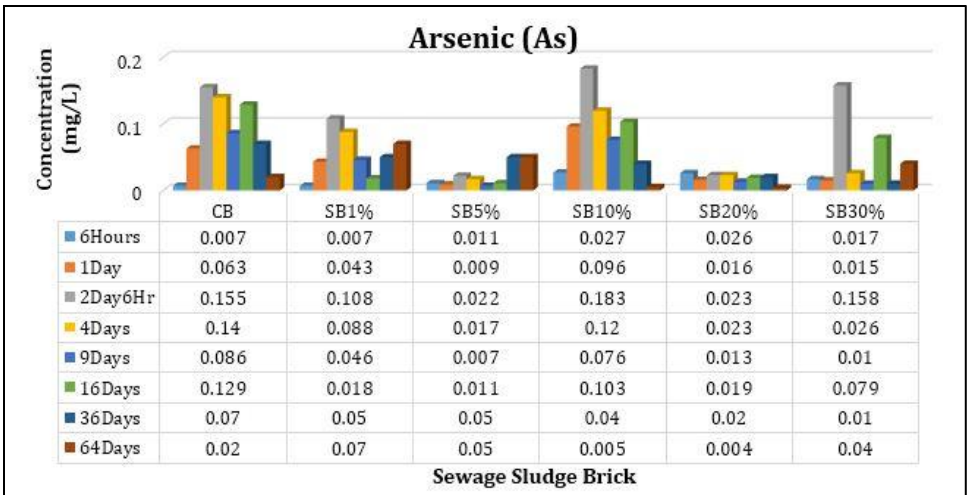


	CB	SB1%	SB5%	SB10%	SB20%	SB30%
6Hours	0.006	0.003	0.002	0.002	0.002	0.002
1Day	0.002	0.002	0.002	0.003	0.002	0.002
2Day6Hr	0.002	0.003	0.001	0.003	0.002	0.003
4Days	0.004	0.002	0.001	0.002	0.002	0.001
9Days	0.005	0.003	0.004	0.002	0.006	0.006
16Days	0.006	0.004	0.003	0.004	0.003	0.003
36Days	0.002	0.002	0.001	0.001	0.001	0.001
64Days	0.004	0.003	0.002	0.002	0.001	0.001

Figure 14. Concentrations of Chromium (Cr).

From the Figure 14, the CB sample shows the highest value at 6 hours and 16 days with 0.006 mg/L. The second higher is at 9 days with 0.005 mg/L followed by 4 days with 0.004 mg/L. For SB1% at period 6 hours, 2 days 6 hour and 64 days, SB5% at 16 days, SB10% at 1 days and 2 days 6 hour, SB20% at 16 days and SB30% at 2 days 6 hour where all of these concentration is average same with 0.003 mg/L. Meanwhile, for CB at 1 days and 2 days 6 hour, SB1% at 1 days and 4 days, SB5% at 6 hours, 1 days and 64 days, SB10% at 6 hours, 4 days, 9 days and 64 days, SB20% from duration of 6 hours to 4 days and SB30% at 6 hours and 1 days where it shows same concentration at 0.002 mg/L. Then, for SB5% at 2 days 6 hour, 4 days and 36 days, SB10% at 36 days, SB20% at 36 days and 64 days with SB30% at 4 days, 36 days and 64 days has the lowest concentration of Chromium at 0.001 mg/L but all of these value is below USEPA requirement which is 5 mg/L.

3.3.8 Arsenic (As)



	CB	SB1%	SB5%	SB10%	SB20%	SB30%
6Hours	0.007	0.007	0.011	0.027	0.026	0.017
1Day	0.063	0.043	0.009	0.096	0.016	0.015
2Day6Hr	0.155	0.108	0.022	0.183	0.023	0.158
4Days	0.14	0.088	0.017	0.12	0.023	0.026
9Days	0.086	0.046	0.007	0.076	0.013	0.01
16Days	0.129	0.018	0.011	0.103	0.019	0.079
36Days	0.07	0.05	0.05	0.04	0.02	0.01
64Days	0.02	0.07	0.05	0.005	0.004	0.04

Figure 15. Concentrations of Arsenic (As).

Figure 15 shows the result of Arsenic (As) from all duration and percentage of sludge in fired clay brick. The result shows a high concentration for CB at 2 day 6 hours with 0.155 mg/L, 0.140

mg/L at 4 days and 0.129 mg/L at 16 days. For SB1% the graph is increase until higher concentration at 2 day 6 hours with 0.108 mg/L and decrease to 0.018 mg/L at 16 days also increased until 64days with 0.07mg/L. Then, SB5% shows a minimum average value range from 0.007 mg/L to 0.022 mg/L. In addition, SB10% obtain the highest value at 2 day 6 hours with 0.183 mg/L followed by 0.120 mg/L at 4 days and 0.103 mg/L at 16 days also decreased until 64 days. For SB20% the concentration is minimum from 0.004 mg/L to 0.023 mg/L. Then SB30% indicate the higher concentration at 2 day 6 hours with 0.158 mg/L and 0.079 mg/L at 16 days with the difference of 50%. From USEPA concentration requirement on Arsenic, it shows that the concentration on each sample is below 5 mg/L.

3.3.9 Summary of heavy metals leachability

Due to the reaction of leaching fluid and bricks sample along the duration of tank leaching test shows that the highest heavy metals that leached from bricks was Zinc (Zn), Barium (Ba) and Vanadium (V). The average trend of leachability test also shows increasing steadily for the first few duration before decreasing until 64 days. Other than that, based on the XRF result, it shows that Barium (Ba) and Zinc (Zn) is the higher element from sewage sludge compared to clay soil. It is also agreed by [10] that Barium and Zinc is found in most land soils at low levels and may be presence of large quantities in the wastewater plant and hazardous waste sites. Different with Vanadium that occurred more higher in clay soil. It is also agreed by [11] stated the element that normally found in clay as complex minerals is Vanadium (V). In addition, metal loss through leaching and organics matter destruction caused the changes in heavy metals concentration [12]. However, the concentration of Zinc (Zn), Barium (Ba), Vanadium (V) and others element of heavy metals obtained is below the standard limit leachate of USEPA and safe to human and environment to be used in the industrial.

4. CONCLUSION

From the research shows that there are similar metals contain in sludge and clay soil. However there are some metal which higher concentration but it does not affect the formation of brick. This indicate that sewage sludge is suitable to replace or mix with clay in term of bricks. For the physical and mechanical properties of sludge brick. The result shows a compressive strength range from 21.6MPa to 11.9MPa, density from 1888.51 kg/m^3 to 1514.02 kg/m^3, shrinkage from 1.63% to 3.38%, water absorption from 8% to 19% and initial rate of absorption from 2.79kg/m2.min to 12.65kg/m2.min. This indicate that sludge brick can be used for a common purpose of brick where the performance comply with the standard bricks. Then the leachability of heavy metals result shows a lower concentration from standard limit of USEPA. Therefore, sewage sludge can be used by incorporating into fired clay brick which as an alternative from disposing to a landfill. The utilization also could produce an adequate properties of brick, providing low cost materials and comply with the environmental standard.

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