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Gases Emissions of Sewage Sludge Brick

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Abstract:
Disposal of sewage sludge is the crucial issues nowadays as the production of sewage sludge waste increased. By incorporated the sewage sludge into fired clay bricks expected to become an alternatives method in disposing the sludge waste. However, the firing process of bricks emits pollutant that becomes threat to environmental as well as human health. Therefore, the investigation of releases the pollutant gases during firing process of manufactured brick that incorporated of sewage sludge was conducted in this research. The bricks were incorporated with 0% and 5% of two type of sewage sludge and was fired at 1050ºC and heating rates 1ºC/min. The characterization of composition for the sewage sludge and clay soil was determined by X-ray fluorescence (XRF) testing. The parameters of gases emissions which are carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxide (NO) and sulphur oxide (SO_2) were measured during the bricks firing process. The result indicates that by incorporation of 5% of sewage sludge into fired clay bricks was comply with the standard requirement for building material usage without the negative effect to the environment.

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I. INTRODUCTION

Due to the rapid growth of urbanization life has generated high sewage sludge every year. The wastewater treatment plant daily receives tons of domestic sewage and regularly pollutes various types of physical, chemical and biological pollutants (Ju et al., 2016). National sewage company in Malaysia such as Indah Water Konsortium (IWK) expected to be generated up to 7 million cubic meters of sewage sludge by the year of 2020 (Kabbashi et al., 2011; Salmiati et al., 2012). According to previous study, sewage sludge waste contained several heavy metals such as arsenic, lead, mercury and nickel that might be dangerous for human health (Cusido and

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Cremades., 2012; Victoria., 2013; Hamood et al., 2017; Xu et al., 2013). The effect of high sewage sludge production has led the major sludge disposal problem. Moreover, the cost and time needed to treat the sludge is very high (Yadav et al., 2014). The most sludge disposal methods worldwide is spreading in the reclaimed land as well as landfilling (Fytili and Zabaniotou., 2008; Pilli et al., 2011). However, these methods of disposal have contributed to the environmental impact such as groundwater pollution from soluble solvents and soil pollutants (He., 2017; Andreoli et al., 2007).

Therefore, immobilization the heavy metals of sewage sludge is the important factor in disposing the sludge waste. Reusing and disposing the sewage sludge must be managed by the municipality in an effective manner (Wang and Wang, 2007). According to several previous studies, by valorization the sewage sludge waste into construction material such as fired clay bricks has potential to be an effectives method to reduce the hazard of the sludge waste (Nair et al., 2013; Wang et al., 2012; Lin and Weng, 2001; Chen et al., 2018). Clay bricks are produces with natural resources, the nature of clay allows for an incorporation of different types of sludge waste (Basegio et al., 2002; Demir, 2006; Ramadan et al., 2008; Rajgor and Pitroda, 2013). This also has been supported by Wiemes et al., (2017) and Samadikun et al., (2018) that stated the composition of sewage sludge is very close to clay brick and can be a potential replacement for clay brick Other than that, study by Liew et al., (2004) and Zhang et al., (2016) shows that by incorporated the sewage sludge into fired clay bricks manufacturing has produced the lighter bricks with better thermal and properties compared to the normal bricks. Therefore, it shows that the incorporation of sludge waste as a building and construction material considered as one of the promising ways of sludge disposal methods.

However, with the grown rapidly of brick industry all over the world has resulted some pollutant gases that released from brick manufacturing industries. One of major sources of greenhouse emissions is brick industries (Hotza and Maia, 2015; Akinshipe and Kornelius, 2017). During the firing process of brick manufacturing, the pollutant gases may derive such as carbon dioxides, nitrogen oxide, sulphur oxide, inorganic fluorine and chlorine compound and also an organic compound (Gonzalez et al., 2011; Kumbhar et al., 2014; Lissy et al., 2018). These pollutant gases give negatives impact not only to environment but also to human health.

The incorporation of sewage sludge waste in fired clay brick manufactured showed positive results in term of properties, however, less attention to investigate on the gases emission during firing of the brick. Therefore, this study was focused on the gases emission that emit during the manufacturing process of the brick.

II. MATERIALS AND METHOD

A. 2.1 Raw materials preparation

Clay soil and sewage sludge was obtained from local brick company located in Yong Peng, Johor, Malaysia and from Indah Water Konsortium (IWK) which located at BatuPahat, Johor, Malaysia. Upon arrival, excess water content from the raw material is removed by drying the sample in an oven for 24 hours at 105^oC. Once the dry process is complete, both materials were crushed to perform the 3.35 micron sieving process. Figure 1 show the raw materials after crushed and sieving process.

Figure 1: Grinded of clay soil and sewage sludge

The chemical composition of both clay soil and sewage sludge was determined by using X-Ray fluorescence (XRF). As for geotechnical testing, the specific gravity and atterberg testing was conducted according to BS 1377-2 (1990). Other than that, the standard proctor testing was conducted to determine the optimum moisture content (OMC) of control brick (CB), Type A sewage brick (SB) and Type B sewage brick (PB) according to BS 1377-4 (2002).

B. 2.2 Brick Manufacturing

Three types of brick that was manufactured which is control brick (CB) and Type A sewage brick (SB) and Type B sewage brick (PB). Table 1 show the mixture ratio in this study for a control

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and sludge brick. This process of samples mixing conducted manually. After homogenized, the mixture placed into 215 mm x 102 mm x 65 mm size of brick mould and compressed. The compacted brick was dried in an oven for 24 hours at 105°C. The last step for manufacturing brick is fired with heating rates at 1°C/min until reached 1050°C of final temperature.

Table 1
Mixture ratio of CB, SB and PB

Mixture	Percentage (%)	Clay (g)	Sewage Sludge (g)	Water (ml)
CB	0	2800	0	476
SB	5	2660	140	510
PB	5	2660	140	507

C. 2.3 Gases Emissions during Firing

D. YES, Air Gas Detector that equipped with gases emissions sensor as illustrated in Figure 2 was connected to furnace to directly measure the emissions from the brick samples. Each temperature from 200ºC, until 1050ºC were recorded at 5-minute intervals. To allow water vapors to be released from the brick body, the initial reading at 100°C has not recorded. Heating rated of 1°C/min were applied during firing process and final temperature was set at 1050°C with two hours soaking time. The emissions from the brick firing measured and subtracted from the sample data.

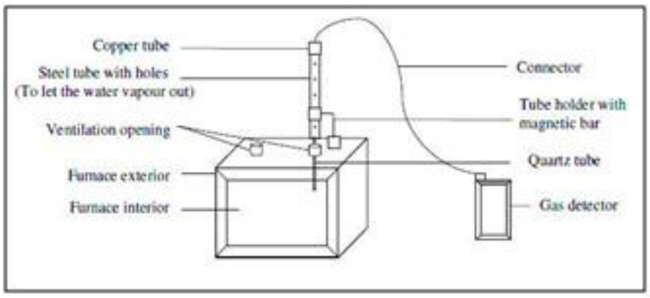

Figure 2. Set-up for measuring the gas emissions testing

III. RESULT AND DISCUSSION

A. 3.1 Properties of raw materials

Table 2 showed the chemical composition of clay soil and sewage sludge (SS). From the results shows that silicon dioxide (SiO_2) with 49.30%, aluminium oxide (Al_2O_3) with 18.40% and iron oxide (Fe_2O_3) with 6.78% is the major composition on clay and the minor composition is magnesium oxide (MgO) with 0.80%, titanium oxide (TiO_2) with 0.94 and manganese oxide (MnO) with 0.4%.

Other than that, from the result shows the highest chemical composition in sewage sludge is silicon dioxide (SiO_2) with 14.30% for Type A sewage sludge (SB) and 16.30% for Type B sewage sludge (PB). Other higher composition is aluminium oxide (Al_2O_3) with 8.98% and 9.79% and iron oxide (Fe_2O_3) with 9.85% for Type A sewage sludge (SB) and 9.35% for Type B sewage sludge (PB). Meanwhile, for nitric oxide (Na_2O), titanium oxide (TiO_2) and manganese oxide (MnO) shows the lowest composition in both sludges.

As can see from the result, the composition of sewage sludge and clay soil was similar and reliable to be as replacement on clay soil. This also supported by Hegazy et al., (2012) stated that due to high silica in sewage sludge, it can be successfully incorporated into clay bricks as well as improve the physical properties of bricks.

Table 2
Characteristics of raw materials

Element	Chemical composition		
	Clay Soil	Type A Sludge	Type B Sludge
SiO_2	49.30	14.30	16.30
Al_2O_3	18.40	6.66	4.79
Na_2O	n.a	0.23	n.a
K_2O	3.09	0.71	1.07
Fe_2O_3	6.78	9.85	9.35
CaO	n.a	6.55	2.40
MgO	0.80	1.15	0.85
P_2O_5	n.a	5.58	6.68
TiO_2	0.94	0.50	0.52
MnO	0.4	0.6	0.5
SO_3	n.a	9.20	4.61
n.a = not available			

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B. 3.2 Gases emission during firing process of brick

C. 3.2.1 Emission of Carbon Monoxide (CO)

D. *During the combustion process has produced a toxic gas that called as CO. Complete combustion of carbon produces carbon dioxide, but incomplete combustion produces largely CO [34]. The emission of CO of all types of brick shows in Figure 6. A study of Akinshipe and Kornelius (2017) described that hydrocarbons was form when the carbonaceous composition in clay starts to burn out at 200-350°C and a more carbonaceous residues that combusted to emit CO. The same result obtained in this study that shows the emissions of CO start to release from 300°C to 700°C with high the high peak of emission at 500°C. The highest emission of CO was recorded from PB followed by SB and CB with 5642ppm, 4347ppm and 1660ppm respectively. According to the Batistella et al., (2015), the high CO concentration found in SB and PB promoted the organic matter oxidation that occured from the high oxygen content and high temperature. After 700°C, CO starts to decrease since the oxidation of carbonaceous matter was complete.*

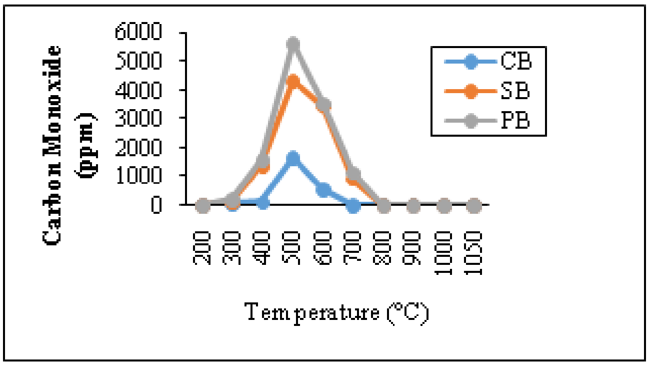

Figure 6: Variation of CO emissions

3.2.2 Emission of Carbon Dioxide (CO_2)

The combustion of carbonates and carbonaceous matter that contained in brick, the releases of CO_2 has been occurred (Torgal et al., 2014). Figure 7 shows the gases emission for carbon dioxide for of all types of brick. From the graph shows that the peak pattern of emissions occurred between 200°C to 700°C with the high peak emissions at 400°C from CB, SB and PB. CB was recorded the low concentration with 2459 ppm. Meanwhile, the SB and PB has increased CO_2 emission with 6345 ppm and 7632 ppm accordingly. The CO_2 for all types of bricks has shown to be reached zero emissions after 1000°C. The result indicate that by incorporated sewage sludge into brick production released the high CO_2 during firing process. The same result was obtained by Chen and Kuo (2016) that shows the higher CO_2 released during firing process when reuse the sewage sludge into brick production compared to conventional brick.

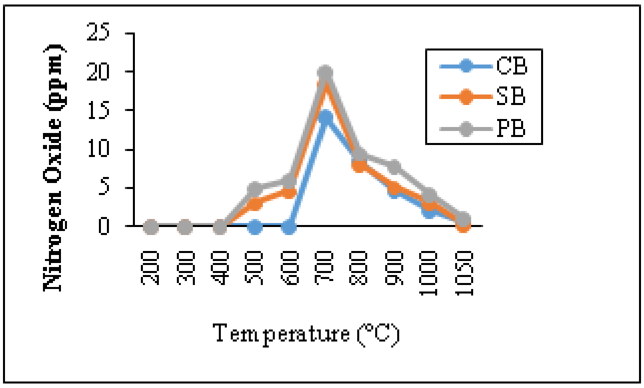

Figure 7: Variation of CO_2 emissions

3.2.3 Emission of Nitrogen Oxide (NO)

Gases emissions of Nitrogen Oxide (NO) of all types of bricks is presented in Figure 8. NO released to atmosphere potentially because of the oxidation of nitrogen by burning at high temperature (Skinder et al., 2014). The result shows that the emissions of NO for CB, SB and PB were in between 400°C to 900°C with high peak of emissions at 700°C. From all sample brick, CB released low NO with 18.5 ppm in contrast of PB and SB with 20.7 ppm and 20.1 ppm accordingly.

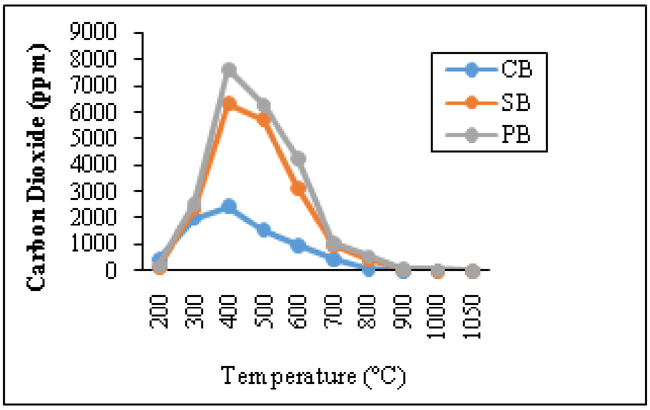

Figure 8:Variation of NO emissions

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3.2.4 Emission of sulphur dioxide (SO_2)

Figure 9 presented the gas emissions of SO_2 for CB, SB and PB. The combustion of sulphur that contained in brick may derived the SO_2 [39]. From the result shows that dominant emissions of SO_2 are from CB in the range between 200°C to 500°C with the high peak of 400°C. Different pattern of SO_2 peak emission for SB and PB that between 400°C -700°C with the high peak of 500°C. By comparing the emission from all sample of brick, SB release lowest SO_2 compare to CB and PB with 0.3 ppm, 0.4 ppm and 0.86 ppm. The same result has found by another researcher that stated oxidation of sulphate compound occurred at the temperature of 400°C(Gonzalez et al., 2006).

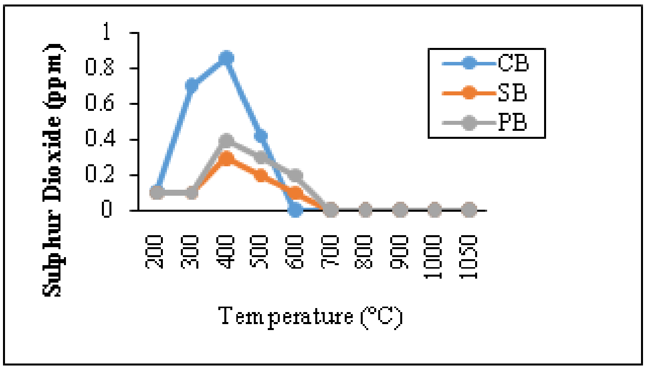

Figure 9: Variation of SO_2 emissions

IV. Conclusion

This study investigated the effect of gases emission during the firing process with the incorporation 5% of sewage sludge into fired clay bricks. The result indicated that the incorporation of sewage sludge increased the CO, CO2 and NO emissions. Moreover, the results show that the SO2 emissions of SB and PB were low compared to other emissions but higher in CB. This result also supported by Ukwatta and Mohajerani (2017) that stated the higher gaseous emissions during the firing process of bricks contributed with the increasing of organic content in bricks.

Therefore, it can be concluded that the use of sewage sludge is suitable as a partial substitute for clay in the manufacture of fired clay bricks as well as an alternative method of sewage sludge disposal. Sewage bricks also show the potential to be environmentally friendly materials

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