Faecal Sludge as Fuel in Industrial Kilns for Brick Production

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1 Introduction

In Kampala, the capital of Uganda, over 80% of the city's 1.7million people use onsite sanitation facilities, which produce faecal sludge (FS). The potential collectable amount of FS exceeds 1,000m^3day^{-1} but less than half is collected and treated. Therefore, a lot of FS remains in the urban environment, posing a public and environmental health problem.

The use of sewage sludge to produce building materials (Taruya, et al., 2002; Weng et al., 2003 Hegazy et al., 2012) and of FS to produce fertilizer pellets (Nikiema et al., 2013) have been previously investigated. FS has an average calorific value of 17.3 $MJkg^{-1}$ TS (Muspratt *et al*., 2014), which compares well with commonly used biomass fuels such as coffee husks and rice husks in industries in Kampala. In a market demand study for FS use in Kampala, 45% of the interviewed companies were immediately willing to use FS if it met their requirements, 30% would use FS if it was compatible with their current infrastructure, and 25% were undecided (Diener *et al*., 2014). However, industries in Kampala continue to grapple with acute shortage of supplies of raw materials for energy.

This research focused on combustion of FS in a pilot-scale kiln constructed in collaboration with an industrial partner, in order to determine the performance and demonstrate to industry the potential for FS to fire industrial kilns.

2 Materials and methods

2.1 Characterization of faecal sludge

Faecal sludge was loaded onto four unplanted sludge drying beds, one with FS from septic tanks, the other with FS from lined pit latrines while two beds were loaded with mixed FS from multiple sources. Mixed composite samples of raw FS were collected from collection and transport vacuum trucks during discharge of the FS onto the beds and tested for chemical oxygen demand (COD), 5-day biochemical oxygen demand (BOD_5), total solids (TS), total volatile solids (TVS), all following standard methods. During the drying process, samples were taken from the beds weekly and tested for TS, TVS, ash content and helminth eggs. At approximately 60% dryness, the FS was tested for COD and CV as well while at 90% dryness, and proximate and ultimate analysis (i.e. C, H O, N, S, heavy metals, ash) are in progress to evaluate potential emissions. The 90% dried FS was removed from the beds and milled into fine particles with a locally fabricated hand-driven milling machine and samples were then analysed for bulk density and helminth eggs.

2.2 Firing trials in a pilot industrial kiln

Unfired bricks, also referred to as "green products," were purchased from Uganda Clays Ltd (UCL), a leading local manufacturer of fired clay products, and then fired in a pilot-scale Hoffman kiln (Figure 1). In total, nine firing trials were conducted. On average, 350 bricks were stacked in the kiln during each firing trial. During the burning, three thermocouples were placed at different points inside the kiln; one at the bottom, another in the middle next to the bricks being fired and the last near the top, with data loggers. The kiln was pre-heated following standard industrial operating procedures to drain any extra moisture from the bricks, and also attain sufficient heat before the dried FS was fed into the kiln from the top feeder holes. Preheating usually took an average of 6 to 7 hours while the firing with FS took an average of 3 to 5 hours. The fired bricks were removed from the kiln after a day or two following cooling.

3 Results

The FS drying took longer than expected due to the heavy rains in Kampala in the months of September to November when the experiment was initiated. Laboratory tests for the FS samples showed a gradual declining presence of helminth eggs throughout the drying process up to 0 viable eggs g^{-1} at 90% dryness in all, except one sample (septic tank FS), which still had 100 viable eggs g^{-1} at 90% dryness. The calorific value averaged 13MJ kg^{-1} TS for the dried FS utilized in the study.

When conducting the firing experiments with dried FS, a range of temperatures was attained at the various points within the kiln. The highest temperatures maintained for one hour were 1,014°C in the combustion zone (bottom), 827°C in the middle and 360°C in the top-most region of the kiln. Figure 2 shows the temperature profile for the combustion zone during the 5th burning experiment, which had the highest temperatures recorded.

Figure 1: The pilot kiln where bricks were fired using dried FS.

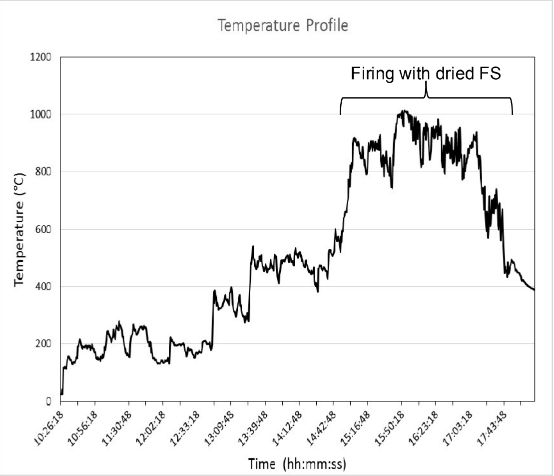

Figure 2: Temperature and time in combustion zone during the 5th firing trial with dried FS.

Prior to firing, the green products had an average compressive strength of 5,500kNm^{-2}, and after firing the bricks had an average compressive strength of 7,300kNm^{-2}. This is comparable to 7,900kNm^{-2} of products fired in the full-scale industrial kiln at Uganda Clays using coffee husks as a fuel. No foul smells were detected while firing the kiln with dried FS.

4 Conclusions

Dried FS can fuel Hoffman brick kilns to achieve temperatures of 800-1000°C, similar to the temperatures achieved in full-scale industrial kilns. If this temperature range is maintained for at least one hour, the products will achieve the desired colour and strength.

Dried FS does not pose health risks at 90% dryness, according to the count of helminth eggs, but even if did, the FS is fired at high temperatures which will destroy any remaining pathogens. The firing of FS on an industrial scale is unlikely to cause foul smells.

Industrial Hoffman kilns which utilize coffee or other husks for energy can in addition, use FS as a sustainable green energy fuel to produce the intended products.

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