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TRANSFORMATION TOWARDS SUSTAINABLE
AND RESILIENT WASH SERVICES

Low cost faecal sludge dewatering and carbonisation for production of fuel briquettes

O. Atwijukye, R. Kulabako, C. Niwagaba & S. Sugden (Uganda)

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Globally, there is an increasing demand for energy to support development needs. The challenge of inadequate energy resources is more pronounced in developing countries/ regions like the Sub Saharan Africa. The quench for energy resources has translated into environmental degradation contributing to climate change. The waste industry is also growing with corresponding increase in population and urbanization. Most of the wastes especially municipal and domestic wastes contribute to global warming. This study sought to devise means of utilizing some waste streams like faecal sludge to partly address the energy deficiency in developing countries, but also trigger studies in similar line. The application of the findings in the study will also solve public health and sanitation issues in urban or peri-urban areas. In this paper, one will find effective and efficient means of dewatering and carbonizing faecal sludge to produce fuel briquettes for cooking.

Background

Developing countries face dual crises of escalating energy demand and lack urban sanitation infrastructure, which pose significant burdens on the environment (Ward, *et al*., 2014). In many of these countries, deforestation and firewood shortage are growing problems not only of the rural areas but also of their high numbers of poor urban populations. Sources of traditional types of fuel (fire wood and charcoal) are becoming more and more exhausted, and the modern fuels (paraffin, coal, mineral oil, electricity) are unaffordable for most of the poor. Additionally, with increasing population in these countries, there is pressure on the environment of, anthropogenic pollution following from the increasing waste quantities (Rahul and Chandi, 2013). As much as the production of other waste materials can be controlled, human waste especially night soil or faecal sludge (FS) will continue to increase with population growth (Heino, 2003).

Currently, FS or its liquid fraction after dewatering is co-treated with sewage in conventional wastewater treatment plants. When dewatered, the solid stream is dried and stored further as the terminal treatment or is co-treated directly with organic solid wastes in composting or anaerobic digestion systems (Semiyaga, *et al*., 2015). According to Strande, *et al*., (2014) and Semiyaga, *et al*., (2015), FS-derived products can be used in various ways namely; as energy, construction material, soil conditioner, feeds, vermicompost and briquettes. The most recognized use in Uganda is as a soil conditioner of dewatered sludge regardless of its pathogenic content. The economic value of the dewatered sludge is low, hence it is sold at a low price (Diener, *et al*., 2014). Of the aforementioned products of FS, the one that is likely to be free of pathogens is the briquettes. The pathogens are killed during the carbonization or pyrolysis process that requires high temperatures of over 300^0C Studies by Ward, *et al*. (2014), show that FS carbonized/pyrolysed at temperatures of about 300˚C or less produce briquettes with higher calorific value (25.6 ± 0.08 MJ/kg) which is comparable to wooden charcoal. The carbonization process produces char which boosts plant growth in the range of 20-120% (Olivier, *et al*., 2015).

Biomass is still the most important source of energy for most of the Ugandan population. Currently the population relying on the various forms of biomass for cooking is 88.9% (fuel wood 78.6%, charcoal 5.6%, agricultural residue 4.7%). Petroleum products and electricity are at 9.7% and 1.4% respectively, (SREP 2014). Firewood is most commonly used by rural households (86%) while charcoal is commonly used in urban areas (70%). In Kampala, 76% of the population use charcoal as their main source of fuel for cooking (Ferguson 2012) and this situation imposes pressure on the natural forests, thereby contributing towards climate change. Several groups of people have started venturing in using organic solid wastes and charcoal dust to make fuel briquettes and these are slowly becoming popular on the market. Most of the briquette making entrepreneur's claim that there is high market but face a challenge of sustainable sources of raw materials. Hence the study into using FS to close the gap in raw material supply since this material is plenty in supply basing on the large numbers of the Ugandan populations using On Site Sanitation (OSS) facilities.

Main objective

The main objective of this study was to ascertain effective and efficient means of dewatering and carbonizing faecal sludge to produce fuel briquettes for cooking at household level.

Specific objectives

- Develop a FS dewatering system to produce FS with a high energy content (low ash content).
- Develop an appropriate carbonizing unit for the dried FS.
- Determine the most appropriate ratios of blending materials for producing high quality fuel briquettes from FS.
- Determine the energy content, metal content and emissions resulting from the use of briquettes, as a way of quality assurance.

Methodology

Construction of dewatering unit

Water for People (2015) and Atwijukye, et al., (2016) developed a low cost decentralised faecal sludge treatment (DEFAST) system in Nyanama, Lubaga division, Kampala; where trial experiments were done for the production of briquettes. In this study emphasis was put on secondary dewatering on drying beds to prepare sludge with less sand for briquettes. Modifications were done on conventional non planted drying bed where the top sand layer was replaced with selected bricks as shown in Figure 1. The bed system had 3 chambers of 600x600mm each where A and B were packed with selected bricks and the other (C) acted as control. Samples were picked every week after thorough turning of sludge and analysed for moisture content. The sludge was transferred to a drying rack after week 3 for further drying.

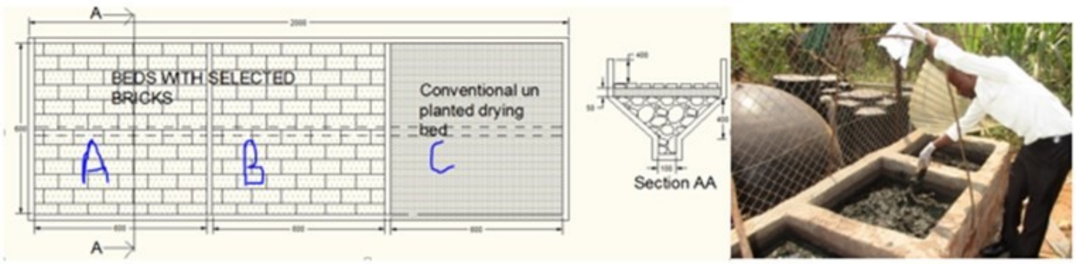

Figure 1. Design of the dewatering plant

Source: Field photo

Carbonisation (making biochar)

Biochar is the carbon-rich product obtained when biomass such as wood, manure or leaves, are heated in a closed container with little or no available air (Lehmann and Stephen, 2009). Currently, carbonization is one of the biggest challenges facing briquette makers. Charring drums and masonry built kilns are presently being developed and tested for charcoal making. Some of them are used for carbonizing solid wastes and other dry organic materials. FS biosolids exhibit variable physical properties compared to commonly used raw materials (solid waste and agricultural residues), and therefore require modifications of current systems/change in operation or designing new systems.

The selection criteria for the most appropriate system was based on energy requirements, retention time in the system to produce char, cost and general operation and maintenance activities involved. The technologies tried included; Masonry retort kiln (Figure 2), traditional earth kiln and metallic charring drum with various modifications because of promising results at initial testing.

Figure 2. Masonry kiln design

Source: Field photos

Metallic drums

The metallic charring drums comprised of ordinary carbonisers for biomass which were modified to suit faecal sludge carbonisation (Figure 3). Dry sludge from racks was broken into pieces of 50 to 100mm to allow easy flow and penetration of heat.

Figure 3. Metallic drums showing the modifications

Source: Field photos

Blending and binders

A binder is very important in the briquetting process using char. The most commonly used binders are cassava flour, clay and molasses. Based on the cost, efficiency, local availability, impact on the environment and effect on calorific value, cassava flour, clay and molasses were main binders considered in this study.

In this study, sludge was blended using mainly charcoal dust and the binders like cassava flour and molasses. The sludge used in this study was emptied by gulpers. Sludge emptied by gulpers already has sand, higher than the other common fuels since gulpers have capacity to empty unlined pits. Addition of clay as a binder was not considered appropriate as it would further increase ash content. This is so because with gulpers, it is possible to empty unlined or partially lined pits, which really have a lot of soil/sand.

Selection of binder
An attempt was made to compare two binders, cassava flour and molasses based on calorific values and ash content. Samples of 100% and 50% FS and the other portion being charcoal dust were prepared and analysed in laboratory.

Selection of suitable blending ratios
Generally, FS alone especially when it is not from container based or specialised urine diversion dry toilets requires blending to make the fuel user friendly and improve on its energy content (Turyasiima, 2016). In Kampala, 30% of pits are unlined, others are fully and partially lined (Semiyaga, et al., 2017) Some pit latrines are not well constructed so that during the rainy seasons, the surface run offs containing sand enters the pits. With less sand it's possible to obtain sludge with calorific value in close ranges with other biomass fuels. Recent studies in Kampala have recorded calorific value of FS as 17MJ/kg TS (Muspratt, et al., 2014).

Results and discussions

Dewatering unit
Dewatering was achieved on a modified conventional non planted drying bed. Selected bricks were used to replace sand in the topmost layer of the sludge drying beds. Results found that the modified unit performed better than conventional beds with sand, where after 3 weeks, 50% of moisture was lost on the modified unit compared to 42% that was lost in the control unit with sand as shown in Figure 4.

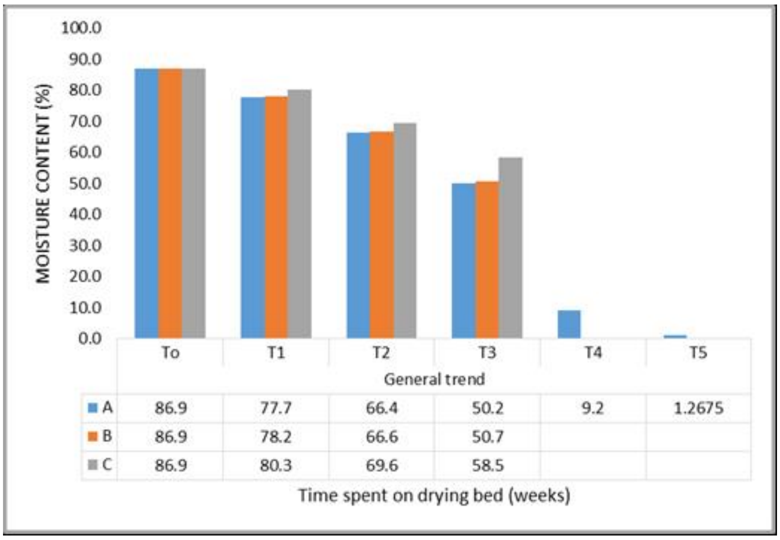

Figure 4. Average time required for each unit throughout the monitoring period

After 3 weeks when the sludge had lost most free water, 5 kg of sludge were picked normally from A and B and further dried on racks. This sludge generally took a week to achieve desired 90% dryness. This result is similar to what was found out under the Sludge to energy enterprise Kampala (SEEK) project. The SEEK project was also looking at various ways of energy recovery from faecal sludge, this involved comparison in performance between faecal sludge-based briquettes and other biomass briquettes. Pelletized sludge took a week to dry from 50% to 90% dryness on drying racks (Turyasiima, et al., 2016).

Carbonisation

Dried sludge cakes of 50mm to 100mm at 90% dryness were the most suitable for carbonization and took about 16-20 hours in the kiln. This stage was key in sanitizing the sludge since most pathogens are unable to survive at high temperatures recorded over 300°c.

Blending, binders and briquetting

The study also found that FS used had inadequate energy content as low as 6.5MJ/KgTS as shown in Figure 7 hence should be adequately blended with other better ingredients like charcoal dust to obtain at least 12MJ/KgTS blending with 50% of other biomass char was recommended, given its sufficient thermal efficiency and ease of use. The lower the FS: Charcoal dust ratio the higher the Calorific Value as shown in Figure 5. A binder is also important, cassava and molasses were used and their performance in terms of contribution to energy and ash content were comparable (Figure 6). Based on current market prices of molasses, US$ 1.13 is required to make 250kg of briquettes, which is comparable to US$ 0.8 required to make 200kg using cassava as a binder.

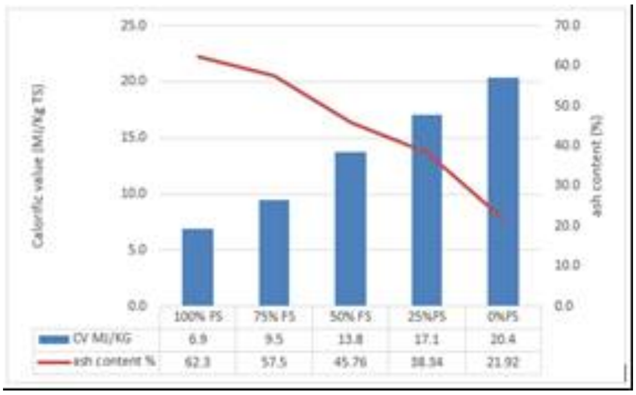

Figure 5. Selection of most appropriate blending ratios

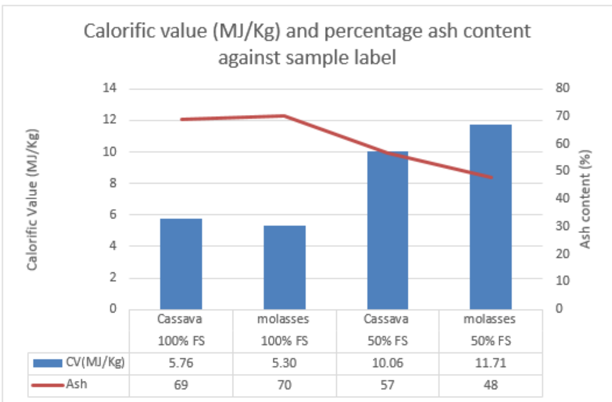

Figure 6. Performance of cassava/ starch and molasses as binders

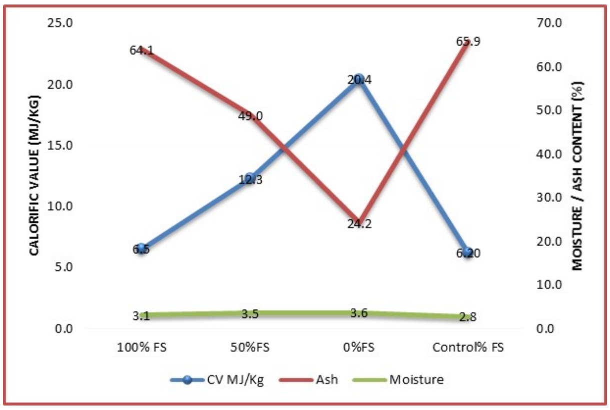

Figure 7. Detailed Calorific value analysis of selected briquettes

Determining the safety

In terms of heavy metals (Pb, Cu) and iron in ash, the concentrations were not significantly different from charcoal dust with 0% FS and given their average values of 41mg/kg and 48mg/kg for lead and copper respectively, they may not have any detrimental health effects. As regards emissions, Feacal sludge briquettes were safer than ordinary charcoal and other biomass mass briquettes.

Conclusion

On a modified dewatering unit which included the control to simulate a conventional un planted drying bed, 50% dryness of sludge was obtained compared to 42% dryness attained on the control after 3 weeks. Carbonisation was successful in a metallic charring drum operated in batch process. When loaded with 0.6m3 of dried sludge at 90% dryness, output was 0.4m3 of char after 16-20 hours. The sludge used required blending with charcoal dust in ratio of 1:1 to obtain 12MJ/kgTS energy content suitable for use. This fuel is also free of pathogens due to carbonisation process, Carbon and particulate matter emissions are comparable to other biomass fuels. However, it's important to do more emission analysis to add confidence to users on top of other benefits like long burning period, quality assurance. One challenge likely to hinder quick market penetration in some areas is people's perception towards sludge, hence need for market demonstrations as well is considering other indirect applications like use in poultry brooding, sauna.

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Contact details

Osbert Atwijukye is a Civil and Environmental Engineer with specific interest in faecal sludge management business models and cost effective technologies. Previously worked as sanitation coordinator at Water For People- Uganda and currently Program Manager at The Water Trust. Also MSC Civ. Eng candidate at Makerere University and Co-Founder Natures Answer (U) LTD.

Osbert Atwijukye,
Makerere University.
Tel: +256 703909751
Email: oatwijukye@yahoo.com
www: https://www.mak.ac.ug/

Robinah Kulabako,
Makerere University.
Tel: +256 772426621
Email: rkulaba@gmail.com
www: https://www.mak.ac.ug/
