Fecal Sludge Treatment and Charcoal Briquette Production

Water for People/AFSRT, Lira, Uganda

John Allen, Oxfam PHE visit to DEFAST Site, September 2018

Background

Charcoal briquette production from fecal sludge (FS) is an option that serves the dual purpose of end-use along with disinfection of pathogens through the carbonization process.

The method of briquette production carried out by Water for People and their partner AFSRT in Uganda consists of combining fecal sludge (40%) with charcoal dust (60%). These ratios have been arrived at through the process of optimization, taking into account the need to maximize the FS content in the briquette while ensuring that the briquette can easily burn like charcoal without FS. The exact ratio could change in another area based on the characteristics of the thickened sludge but would likely be similar.

Thickening and Drying

Sludge thickening is the first step in the process, and this is achieved in a sedimentation tank. This allows for a uniform, homogenous fecal sludge that is mixed from multiple sources. Next, sludge is dewatered in an unplanted drying bed. A couple modifications have been made to allow for a more effective dewatering process. Sludge is loaded onto the drying bed, which has a sand layer with a sump and a layer of blocks with openings on top of the sand layer. This set-up allows for the thickened sludge to be loaded on top of the block layers and the leachate to collect to drain out underneath (which is then treated in a DEWATS type wastewater treatment configuration). The feature of the block layer is important as it allows sludge to be easily removed from the drying bed, without collecting sand from the drying bed. It is important to minimize that amount of sand in the final briquette as this will impact the quality of the end product. The team has also previously experimented with using a geotextile layer to serve this same purpose, but the performance has not been as high and the geotextile requires periodic replacement. The drying bed is covered with translucent plastic/frp roofing.

Figure 1a: Unplanted drying bed. The coloration on the walls show the sludge depth during loading.
Figure 1b: Blocks as the upper layer of the drying bed

Dewatering time in this location (Lira, Uganda) typically takes about three weeks. Lira experiences wet and dry seasons, and there is some but not great variation in the time required for dewatering. The target end point moisture content is 10% and this is an important parameter to meet to enable an effective carbonization process. However, in practice moisture content is not typically measured but rather operators through experience can detect that the sludge has sufficiently dried. It is only partially dried at this stage and so the sludge is removed by shovelling out the thickened, dewatered sludge and onto an area for solar drying. Operators know when the sludge has achieved sufficient secondary drying at this stage, which can be in as little as a week but is more typically about two-three weeks. Approximately six weeks are required overall for the entire drying process.

Figure 2a: Primary dewatering bed on the left and secondary drying on the right
Figure 2b: Secondary drying

The sizing, design, and operation of the sedimentation tank, dewatering beds, and leachate treatment components is beyond the scope of this document. It is suggested to consult the literature on design of DEWATS wastewater treatment units and on unplanted drying beds. However it is important to note that these components will account for the vast majority of land area required to run the FS briquette production operation, including the multiple stages of treatment necessary for septage from the thickening tank and leachate from the dewatering bed.

Carbonization

The fully dried sludge cake (10% moisture content) is then broken up into pieces for carbonization. The process has been designed for chunks of 50-100mm, however in practice larger width/diameter pieces are used.

Figure 3: typical size of FS chunk for carbonization

Carbonization is carried out in a metallic kiln. The team has experimented with different types of kilns, including earth kilns and masonry kilns, and has found the metallic kiln with a chimney to be simple and effective. In practice the kiln in Lira does not use a chimney.

The kiln has a partially conical lower section with a flat bottom. Kindling and small firewood is added to the bottom, by tilting the kiln and igniting the fire. Once a sufficient fire has started, the fecal sludge chunks are slowly added to the kiln. Fecal sludge is gradually added as the temperature increases and the chunks begin to blacken, and this takes place over about 2-3 hours until the kiln is ¾ of the way full. The kiln is left covered for about 5-6 hours. In total, about 60 kg of fecal sludge is carbonized per batch in the kiln.



Figure 4a: Kiln for carbonization
Figure 4b: Partial conical bottom of kiln
Figure 4c: Optional chimney component

After carbonization, the chunks must be checked if they are fully blackened/carbonized. Pieces that have not fully carbonized must be rejected and left for a second round of carbonization. Carbonization is the trickiest part of the process as it is essential that sludge of the right moisture content is added and that a full carbonization process is carried out.

Figure 5: The chunk on the left is large and has only partially carbonized.
The pieces on the right are fully carbonized

Crushing, Sieving, and Mixing

Fecal sludge char is then added in a crusher to produce particles small enough for briquette production.

Figure 6: Crusher for carbonized fecal sludge

Crushed char is then loaded onto a mechanical sieve. Particles not passing through the sieve are again loaded into the crusher.

Figure 7: Sieving of crushed fecal sludge char

FS char is then added to char from another source at a ratio of 40% FS char / 60% charcoal dust. In Uganda, charcoal is widely used and it is possible to acquire charcoal dust from middlemen associated with the charcoal business. Because of its availability, low cost, and no need to carry out an additional carbonization process, charcoal dust is the most appropriate material in this context. In locations where charcoal dust is not available, it must be created through an additional carbonization process of biomass, which must be carried out separate from the FS carbonization. The selection of biomass is based on availability of cheap, locally available raw materials. Mixing of FS char and non-FS char is done in a mixer to achieve a uniform blend of the two components.

Figure 8a: Mixer for blending char, exterior
Figure 8b: Mixer, interior

Binding

The char blend must be held together in order to produce briquettes which do not crumble. The selection of binder is based on locally available material which has been shown to work effectively. In Lira, Uganda molasses is the preferred binding material but it is not always available. As a substitute, cassava flour in boiled water is used.

Figure 9: Preparation of cassava flour binder

The cassava flour mixture is then added to the char blend. Additional water is added until the mixture becomes sufficiently moist and workable for binding during extrusion. Moisture is not measured but rather operator experience is used to approximate when the char mix achieves a sufficient moisture to be workable and result in well-binded briquettes during extrusion.


Figure 10a: Using cassava flour and water to moisten and bind the char
Figure 10b: Moist char after binder and water has been added

Extrusion

Extrusion is the process in which the briquette is molded from the char mixture and removed as an intact unit. In Uganda, there is an existing biomass briquette industry and so there are extrusion machines available on the local market.

Molds can produce briquettes sized to a specification of a type of cookstove, such as those for honeycomb briquettes. The stick extrusion machine produces stick briquettes that can be used in a fire.


Figure 11a: Extrusion machine with hatch for loading char
Figure 11b: Extrusion power unit and corkscrew shaft for stick briquette extrusion

It is necessary to manually manipulate the char in the loading unit so that sufficient char falls down into the mold.

In the past there have been problems with breakage of the shaft for the stick briquette extrusion, however this new extrusion machine is of a better quality. This machine is available in the Uganda market, because of the high demand for charcoal and resulting existing practice of biomass briquette production.

Figure 12a: Working char into the mold and extrusion
Figure 12b: Extrusion of stick briquettes

After extrusion, stick briquettes are manually transferred carefully to a tray so that they do not break.

Figure 13: Stick briquettes

Additionally, honeycomb briquettes for use in cookstoves designed for this shape of briquette are made using a manual press for extrusion. Greater moisture content is required when operating this press to get a workable mixture that can be removed using the mechanical device.

Figure 14a: Honeycomb extrusion press
Figure 14b: Honeycomb extrusion

After extrusion, the formed briquettes are finally left for solar drying for 2-5 days.

Figure 15: Finished briquettes left for solar drying

Production Rates

The DEFAST plant is producing briquettes at a rate of 1500 kg per week, while taking in about 12 m^3 of raw fecal sludge per week. This could be used to approximate that 125 kg of briquettes may be produced per m^3 of FS.

The production rate itself is not at the full capacity of the plant. The current limiting factor is the volume of fecal sludge they are able to collect.

The briquette production crew consists of three members working an 8 hour day. They have produced up to 1200 kg in a day, but their typical maximum output is 500 kg per day when making briquettes.

Honeycomb briquettes are labor intensive in operating the manual press. Two people can produce about 100 honeycomb briquettes per day.

Beyond a certain volume of sludge, an increase in capacity of drying beds would be necessary. The literature on loading rates and sizing of unplanted drying beds may be consulted for this purpose.

References

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