# Production of Pellets and Electricity from Faecal Sludge

Resource recovery from faecal sludge treatment endproducts could help offset faecal sludge treatment costs. In Kampala, Uganda, the SEEK (Sludge to Energy Enterprises) Project is evaluating faecal sludge pellets that can be used as a solid fuel and to produce electricity. Moritz Gold[1], Charles Niwagaba[2], Florian Studer[3], Wim Getkate[4], Mohammed Babu[5], Linda Strande[1]

## Introduction

Faecal sludge management (FSM) in low-income countries frequently fails due to a lack of financial resources [1]. However, FS treatment endproducts can generate revenue to offset FSM costs [2, 3]. In Sub-Saharan Africa, the following FS treatment endproduct markets were identified: as an industrial fuel, as a source of protein for animal feed, as a source to produce biogas, as a component in building materials, and as soil conditioner or fertilizer [3]. Currently, the only resource recovery from FS that is in use is as a soil conditioner; the other markets remain untapped even though they have higher revenue potentials [2, 4]. Reasons for this include a lack of reliable implemented technologies for resource recovery and undeveloped markets for FS treatment endproducts. The ongoing SEEK Project, and the recently completed FaME (Faecal Management Enterprises) Project, focus on developing technologies to maximise resource recovery, on identifying new endproduct markets, and on developing business models to increase the potential of resource recovery.

## Co-processing

FaME identified that to scale solid fuel production from FS requires the optimisation of FS drying, the reduction of ash content and increasing the quantities of treatment products. Co processing of FS with other urban biowastes could be a way to tackle all three of these shortcomings, while simultaneously contributing to solid waste management. An assessment study was conducted to identify the most suitable waste streams for co-processing. Biowastes were evaluated with Multi Criteria Analysis and the main criteria were: availability, accessibility and physical chemical properties. Based on secondary data and stakeholder interviews, 28 different biowastes were identified and ten were shortlisted for in-depth analysis. All the waste streams that were identified are currently in use and have competing market value, except for drinking water treatment sludge and market waste. The ones identified as most suitable were: brewery waste, sawdust, coffee husks, maize cobs and market waste.

## Pelletising

Cost-effective drying is key for the financial viability of solid fuel production from FS. SEEK is working with Bioburn, a Swiss engineering enterprise, that has designed an innovative pelletising machine, which is able to process wet biowastes into pellets (Photo 1). The pellets can be passively dried to 90 %, for example, in greenhouses. The pelletising machine is currently in use at the National Water and Sewerage Corporation (NWSC) Lubigi Wastewater and Faecal Sludge Treatment Plant in Kampala. Durable pellets could be produced from FS with 50 – 60 % dryness without a binder. The result is that space for drying beds could be reduced and/or treatment capacities increased. Additionally, pelletising increases the product's quality and bulk density, reducing transport and storage costs. At NWSC Lubigi, more than 10 000 $m^2$ are used for dewatering, drying and storing 400 $m^3$ FS per day.


Moritz Gold

Photo 1: Pellets produced from faecal sludge in Kampala, Uganda.

## Gasification

In Uganda, electricity demand significantly outstrips electricity generation and only 14 % of the population nationally has access to electricity. The pellets produced are being used in gasification for electricity production. Converting FS for energy could contribute towards meeting present and future energy needs. FS has an energy potential comparable to other solid fuels, and pellets work well as a fuel due to their uniform size and dryness. The ash produced, however, reduces this energy value and due to the high temperatures during gasification could melt and form "clinker" which could clog the gasifiers. Preliminary results indicate that the high variability and the high ash content of FS remain key challenges for gasification. In Kampala, for example, ash content in dewatered FS is 30 – 50 % of the dry matter.

| Parameter | Unit | FS Kampala | FS Dakar | Wastewater sludge | Excreta | Limits biosolids land application |
|---|---|---|---|---|---|---|
| Cadmium | ppm | < 2.0 | < 1.8 | 4 – 10.1 | 0.3 – 0.4 | < 39 – 10 |
| Chromium | ppm | 485 | 401 | 190 – 530 | 0.6 | < 1 200 – 900 |
| Copper | ppm | 114 | 216 | 330 – 400 | 22 – 31 | < 1 500 – 800 |
| Mercury | ppm | < 0.9 | < 0.8 | 2.1 – 5.4 | 0.2 | < 17 – 8 |
| Nickel | ppm | 24 | 30 | 40 – 45 | 2.1 – 4.7 | < 420 – 200 |
| Lead | ppm | 28 | 59 | 220 – 365 | 0.6 – 1.4 | < 900 – 300 |
| Zinc | ppm | 646 | 918 | 1 132 – 4 900 | 132 – 305 | < 2 800 – 2 500 |

Table 1: Heavy metal concentrations in faecal sludge compared to wastewater sludge, excreta/faeces and limits for biosolids land application in the USA [4].

Moritz Gold

Photo 2: Drying beds at NWSC Lubigi Wastewater and Faecal Sludge Treatment Plant in Kampala, Uganda.

## Environmental impact

Wastewater sludge is already used as a solid fuel by industries in Europe, Japan and the US. Analytical results indicate that the elemental composition of FS is comparable to wastewater sludge (i.e., carbon, hydrogen, nitrogen, sulphur, and chlorine) [4]. This implies that the success of combusting wastewater sludge can be transferred to FS. However, the pollutants produced, which include dioxins, furans, nitrogen oxides ($NO_x$), nitrous oxide ($N_2O$), hydrogen chloride (HCl), sulphur oxides ($SO_x$) and heavy metals, would need to be controlled during energy recovery and ash disposal. Yet, large scale industries with existing emission control measures could be the target customers. Although FS has concentrations of heavy metals that are significantly lower than in wastewater sludge (See Table 1), they are still higher than those found in excreta. This highlights the potential of energy recovery from faeces collected from source separation toilets because of its' lower concentrations of heavy metals, ash and nitrogen.

## Market development

Processing FS into fuel pellets and subsequent gasification could provide revenue to improve services throughout the FSM service chain, and also increase energy supplies. Fuel pellets and electricity have a higher market value than the use of FS as a soil conditioner. However, increased revenue needs to be balanced with the associated increased costs of production. SEEK is assessing the market environment for pellets, electricity and resource recovery technologies in Kampala, and this will be used as the baseline to develop implementation scenarios and business models. Results from the waste assessment, technology development and market assessment will also feed into a financial analysis of implementation scenarios at different scales and assist in the development of a resource recovery strategy for NWSC.

## Ongoing research

Ongoing research is focusing on optimising the drying of FS and the pellets and on increasing the quality of pellets by reducing the ash content, i.e., by using geotextiles on the sand filter layer of drying beds and co-processing the FS with suitable biowastes (Photo 2). In Tanzania, pilot-scale research will be conducted to develop dewatering and drying technologies that reduce ash content. This is required to meet the needs of industries and for gasification. Research into the most suitable gasification technologies for FS is also being done. In order to provide resource recovery solutions for different markets, in addition to combustion and gasification, the potential of slow pyrolysis and the hydrothermal carbonization of FS will be investigated in Switzerland and Tanzania. Char from hydrothermal carbonization has the potential to be used as a substitute for wood-based charcoal or as a soil amendment.

## Conclusion

High moisture and ash content, and emissions and heavy metals in the ash produced are challenges for energy recovery from FS. However, these challenges could be overcome with the appropriate technologies. FS resource recovery has the additional benefit of reducing pathogen transmission pathways and land requirements for treatment plants. Large-scale energy production could provide increased revenue, offsetting treatment costs, and act as an incentive to sustain FS treatment and meet market demands.


[1] Bassan, M., Koné, D., Mbéguéré, M., Holliger, C., Strande, L. (2014): Success and failure assessment methodology for wastewater and faecal sludge treatment projects in low-income countries. Journal of Environmental Planning and Management. <http://www.tandfonline.com/doi/abs/10.1080/09640568.2014.943343#>

[2] Gold, M., Niang, S., Niwagaba, C.B., Eder, G., Murray Muspratt, A., Diop, P.S. and Strande, L. (2014): Results from FaME (Faecal Management Entreprises) – Can dried faecal sludge fuel the sanitation service chain? 37th WEDC International Conference, Hanoi, Vietnam.

[3] Diener, S., Semiyaga, S., Niwagaba, C.B., Muspratt, A.M., Gning, J.B., Mbéguéré, M., Ennin, J.E., Zurbrugg, C. and Strande, L. (2014): A value proposition: Resource recovery from faecal sludge – Can it be the driver for improved sanitation? Resources, Conservation & Recycling *88*, 32–38.

[4] Gold, M., Ddiba, D., Seck, A., Sekigongo, P., Diene, A., Diaw, S., Niang, S., Niwagaba, C., Strande, L. (submitted) Faecal sludge – a solid industrial fuel?



[1] Eawag/Sandec, Switzerland
[2] Makerere University, Uganda
[3] Bioburn, Switzerland
[4] Centre for Research in Energy and Energy Conservation (CREEC), Uganda
[5] National Water & Sewerage Corporation (NWSC), Uganda



This research is funded by the Symphasis Foundation, REPIC (Renewable Energy & Energy Efficiency Promotion in International Cooperation) and the Swiss Development Corporation, and was conducted as part of the SEEK (Sludge to Energy Enterprises in Kampala) Project <http://www.sandec.ch/seek>.



Contact: moritz.gold@eawag.ch or linda.strande@eawag.ch