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FOR ALL IN A FAST CHANGING WORLD

Results from FaME (Faecal Management Enterprises) – can dried faecal sludge fuel the sanitation service chain?

M. Gold, S. Niang, C. B. Niwagaba, G. Eder, A. Murray Muspratt, P. S. Diop & L. Strande, Switzerland

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In Sub-Saharan Africa, sanitation needs for the majority of the urban population are met by onsite sanitation technologies. Cities grapple with management of faecal sludge (FS) once these technologies become full, while at the same time the urban economy is resource intensive. The FaME (Faecal Management Enterprises) project addressed both of these issues by identifying untapped markets for FS treatment products. Industries have a high fuel demand and FaME demonstrated that dried FS could be used as a solid combustible in industrial kilns. Existing treatment technologies were adapted for fuel production, and its application was demonstrated in two pilot kilns. Historically used as a soil conditioner, processing of FS to a solid biofuel could provide higher revenues, thereby providing a financial incentive for stakeholders to enhance FS management service along the entire sanitation chain.

Introduction

Worldwide, the sanitation needs of 2.7 billion people are met by onsite sanitation technologies such as pit latrines and septic tanks (BCG, 2013). Past efforts to increase access to sanitation have mainly focused on provision of sanitation technologies at the household level. However, the entire faecal sludge (FS) management service chain needs to be in place to meet the human health goals of improved sanitation, to hygienically separate human excreta from human contact (WHO & UNICEF, 2013). Collection, transport and treatment services are required to remove FS, the (semi-) liquid waste accumulating in onsite sanitation technologies, from the household level, and ensure safe enduse or disposal. The need is greatest in densely populated urban areas, where large amounts of FS are produced and risk of exposure to pathogens is high. The current lack of comprehensive FS management services results in dumping of FS directly into the urban environment, jeopardizing human and environmental health.

Currently, in Sub-Saharan Africa, the energy and nutrient value of FS is mostly wasted by landfilling or discharge of inadequately treated FS into the environment. One reason for this is that the sanitation service chain is financially unsustainable, with a lack of public or private investments. Public investment can be influenced by macroeconomic benefits such as reduction of water-borne diseases, however private investment must be driven by financial returns (Trémolet, 2013). Instead of only perceiving FS as a disposal problem, the nutrients and energy contained in FS can also provide business opportunities in urban areas of low-income countries (Koné, 2010). Service chains designed for the recovery of nutrients and energy from FS can provide resources for urban development, and be a financial incentive for public and private investment (Heierli et al., 2004; Trémolet, 2013).

Onsite sanitation technologies with FS management services can provide sustainable sanitation, and depending on the local context can be five times less expensive than sewer-borne solutions (Dodane et al., 2012). In Europe and the United States, among others driven by high costs for fossil fuels and legal regulations, sludge from wastewater treatment and other waste products such as plastics, tires and biomass fuels are used as alternative fuels in cement production. In addition to being less expensive overall, a similar market for FS by a large-scale industry could represent a significant demand and revenue source to help fuel the sanitation service chain in low-income countries. However, in contrast to wastewater sludge, at the beginning of the Faecal Management Enterprises (FaME) project, FS had never been considered as a combustible and the energy potential of FS was not known. Moreover, cost-effective drying technologies needed to be developed for its application as a solid fuel, given the low solids content of FS.

The objectives of the FaME project were to transfer existing knowledge and fill knowledge gaps that limit scientific decision making and market implementation for FS treatment products in low-income countries, and to identify financial incentives for stakeholders to enhance the performance of FS collection, transport and treatment services.

Methodology

The FaME project consisted of an international multi-disciplinary consortium of researchers, consultants and sanitation practitioners. For knowledge sharing and to translate research findings into policy and practice, FaME included partners from North and South and public and private sector. Field research was conducted in Dakar, Senegal; Accra, Ghana; and Kampala, Uganda, to allow cross-comparison throughout Sub-Saharan Africa, and to draw relevant conclusions that are transferable to other countries. The FaME project was comprised of the following activities:

1. **Market Demand:** A study was conducted in Kampala, Dakar and Accra to identify markets and the market value for FS derived endproducts.
2. **Technical Feasibility:** Calorific value of FS was determined in Dakar, Kampala and Kumasi, Ghana. Innovations to enhance FS drying technologies were evaluated in Dakar. Pilot-scale kilns were constructed in Dakar and Kampala to demonstrate the use of FS as a solid biofuel in industrial kilns.
3. **Financial Viability:** A model was developed and implemented to assess the financial viability of FS service chains with resource recovery from FS treatment endproducts.
4. **Dissemination:** Research findings were communicated to relevant stakeholders.

Results

Market demand

As reported in Diener et al. (in press) and summarized in Table 1, the following five FS treatment endproducts were identified as being the most feasible options for resource recovery from FS:

- dried FS as an industrial solid fuel;
- treated FS as a soil conditioner or organic fertilizer;
- biogas from anaerobic digestion of FS;
- protein derived from larvae in FS processing to be used as animal feed;
- dried FS for use as a component in building materials

There was relatively high market demand among industries for use of FS as a solid fuel. The technical feasibility component of the FaME project was designed to address how to use FS as a solid fuel (see below). The greatest demand for FS as a solid fuel was identified in Kampala, with 45% of interviewed industries expressing interest to use dried FS. A variety of alternative fuels are already being used that could be supplemented by FS. In Accra and Dakar, the demand was less because the use of electricity and liquid fuels was more pervasive than solid fuels.

Other innovative enduses that have not yet been implemented at full-scale include anaerobic digestion, protein production and using FS as component in the production of building materials. Although anaerobic digestion is widely used to treat wastewater sludge and produce biogas, this technology has not yet been adapted for the full-scale treatment of FS in urban areas. Protein can be produced from insect larvae that are used to treat FS; the larvae can then be used as a substitute for fishmeal and for protein sources in animal feed (Nguyen, 2010). FS could also be used as a component in the production of building materials such as bricks (Liew, 2004). However, this option was ruled out as industrial producers expressed concern about the consistent characteristics of FS.

FS used by famers in Dakar and Accra as a soil amendment is the only FS treatment endproduct already in use. Yet, farmers spoke of a lack of continuous supply, that it was not a traditional practice, and had concerns about odour and associated health risks. These concerns could be overcome by increasing product quality (e.g., composting and pelletizing) and marketing of FS treatment endproducts (Rouse et al., 2008). 58% of the farmers interviewed stated that they would be willing to use FS if it were available.

The market potential of FS treatment endproducts is dynamic and varies greatly between cities, and is influenced by such factors as FS characteristics, existing markets, local industries, subsidies, user perceptions, and availability of competing products. Currently, the market potential of FS is untapped and most of it is landfilled, discharged to the environment or sold below value. Table 1 summarizes revenue estimates of FS treatment endproducts. It highlights that the potential energy recovery options provide higher gross revenues when compared to selling it as a soil amendment. Treatment technologies and decision support tools need to be developed for each FS endproduct. This would allow production to respond to specific market demands and assist in determining the most favourable FS endproduct for each local context. The entire results of the market demand study are included in Diener et al. (in press).

Table 1. Quantities of faecal sludge and estimated gross values of treatment endproducts (Diener et al., in press)

	Unit	Dakar	Accra	Kampala
Faecal sludge currently legally discharged	tons dry solids/day	6	26	16
Fuel – combustion	USD	NA*	NA*	4,243 – 1,128,691
Protein	USD	40,435	235,747 – 255,216	129,168
Fuel – biogas	USD	NA	248,004 – 257,964	158,743
Soil conditioner	USD	12,480	53,664 – 134,160	81,120

*Further research estimated a take-up price for the FS fuel of 59 USD/t in Dakar and 85 USD/t in Accra. This could generate a gross value of USD 110,448 and USD 689,520, respectively.

Technical feasibility

Calorific value

Analysis of FS from different onsite sanitation and FS treatment technologies in Dakar, Kampala and Kumasi revealed a promising energy potential for using FS as solid fuel. On average, the calorific value was 17.3 MJ/kg dry solids, thus, highly competitive with local biofuels like coffee husks, rice husks, and sawdust, as shown in Figure 1 (Muspratt et al., in press). Results were similar between the three cities but anaerobic treatment of FS reduced the calorific value for energy recovery.

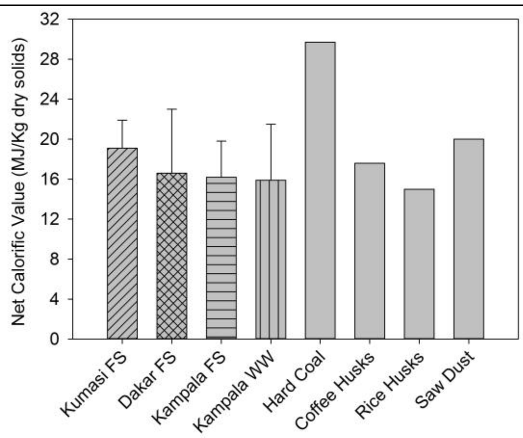

Figure 1. Calorific value results for faecal sludge in comparison to wastewater sludge, coal and common biomass fuels used in Sub-Saharan Africa in MJ/kg dried solids.

Source: Muspratt et al. (in press)

Drying technologies

Cost-effective drying methods are key for energy recovery from FS (BMGF, 2013). Through the FaME project, research was conducted on technology innovations to increase the drying rate of FS at a pilot-scale research facility constructed by FaME (see Photograph 1). Treatment goals were to meet customer demand (e.g. 90% dryness), and to reduce the necessary treatment footprint and costs. In the arid climate of Dakar, greenhouses did not increase the drying rate, other than during the rainy season. However, mixing or turning the sludge did increase the drying rate, and could result in a reduction in required land area of around 25% (Seck et al., submitted). The FaME partner Waste Enterprisers has also built a pilot-scale greenhouse in Mombasa to further experiment and optimize the operating parameters for solar drying of FS.

Photograph 1. Unplanted drying beds at the FaME research facility at Cambérène Wastewater and Faecal Sludge Treatment Plant in Dakar, Senegal.

Pilot kilns

During the market demand study, industries in all three cities requested pilot-scale implementations of FS as a solid fuel prior to assessing its feasibility, quality, transportation, distribution and use in kilns and boilers. Pilot-scale kilns were constructed and are being operated in Dakar (see Photograph 2) and Kampala (see Photograph 3) to collect scientific data and demonstrate its technical feasibility to stakeholders. In Dakar, the kiln is demonstrating the potential use for regeneration of waste oil whereby the kiln in Kampala the use for brick production.

In Dakar, preliminary experiments achieved kiln temperatures between 174 and 261 °C with 5 kg and temperatures exceeding 500 °C with 15 kg dried FS. This means meeting the requirement of the oil regeneration company of 360°C. In preliminary experiments in Kampala, combustion of FS was able to heat the kiln to temperatures between 150 and 1015°C. A temperature of around 800°C was maintained which is the requirement of the brick production company. The brick strength appeared to be similar to products produced by industry, but many of the bricks were blacked by smoke, and temperature had an inhomogeneous temperature distribution within the kiln. These shortcomings are currently being addressed and firing with FS is also being compared to firing with coffee husks.

In general, it was a challenge to maintain controlled conditions in which the fuel performance was not influenced by kiln construction and operation. These preliminary results are very promising, and further optimization of kiln design and operation is ongoing. In Kampala, the kiln was already used for demonstration to various stakeholders and the media. Analysis on fuel characteristics (e.g. carbon, nitrogen, sulphur, ash, heavy metals) on dried FS samples in Dakar, Accra, Kampala and Mombasa are underway to estimate emissions from combustion and to provide scientific data for informed decision-making. Consultations with industries revealed that the ash content of FS might need to be reduced to meet industries quality standards. Viable helminth eggs were quantified in dried FS as an indicator of hygienic quality as they are highly resistant to treatment. In Dakar, the number of helminth eggs was higher than that recommended by the World Health Organization (WHO) for use in agriculture (WHO, 2006; Seck et al., submitted). However, this is an additional benefit to enduse as combustion, as the risk of exposure to pathogens can be reduced just through protective measures for workers that are handling the dried FS, as there is no other risk from exposure.

Photograph 2. Pilot kiln in Dakar, Senegal

Photograph 3. Pilot kiln in Kampala, Uganda

Financial viability

Revenues from FS treatment endproducts are limited by losses of FS along the FS management service chain. FS volume flow analysis identified that it in all three cities, less than 50% of the FS volume produced in onsite sanitation technologies gets collected by FS collection and transport trucks. Reasons are unaffordable emptying services and inaccessibility of onsite sanitation technologies. Of the FS collected, a high volume which could not be quantified gets dumped into the environment. In all three cities, at the time of data collection, treatment capacity was low or inexistent. Therefore, the revenue generated by potential FS treatment endproducts could not be compared to treatment costs to assess its overall financial viability. However, FS processed for combustion in industries can provide significantly higher revues compared to enduse as soil conditioner, e.g. to public or private treatment operators to partial or fully offset treatment costs. This revenue could provide an incentive for treatment operators to have an interest in enhanced performance of FS collection and transport services and reduction of dumping fees. Not considering differences in treatment costs, in the three cities estimations indicate that FS as a solid biofuel could produce revenues 2 to 35 times higher compared to enduse as a soil conditioner in agriculture. The large number of influencing parameters (see above), the different contexts and the fact that FS is currently only used to a small extend as soil conditions explains the high variability in revenue potential (also see Table 1).

Dissemination of research findings

Research results were jointly disseminated throughout the project by all partners. Dissemination included workshops with stakeholders, pilot kiln demonstrations, consultation with industries, scientific publications and presentations at conferences and national sanitation utilities. Video production is ongoing to effectively dissemination findings of FaME to both sanitation practitioners, students of environmental engineering and a broader non-scientific audience. Further information can be found at www.sandec.ch/fame.

Conclusions

FaME was innovative in researching the use of dried FS as a fuel for industries. FaME revealed untapped markets for FS derived endproducts and demonstrated the technical viability of using dried FS as a solid industrial fuel. The revenue generated from resource recovery of FS through combustion in industrials kilns has potential to increase FS management services. Key conclusions of FaME include:

- In Sub-Saharan Africa, untapped markets exist for FS treatment endproducts. Market demand and revenue potential is not universal but depends on the local market environment.
- Based on its calorific value, dried FS is competitive to other fuels used by industries.
- Technology innovations can significantly reduce the footprint for unplanted drying beds and open up opportunities for resource recovery.
- Pilot kilns have demonstrated the potential of using FS as a fuel. This research is continuing to provide industry with necessary information for upscaling.
- Enduse of dried FS in industrial kilns can create significantly higher revenues than using it as a soil conditioner in agriculture.
- The capacity for resource recovery from FS could be greatly increased through improvement of cost effective collection and transport services, which would greatly increase available FS

- Further optimization of treatment technologies to produce solid fuel products will also improve the potential for use of FS as a fuel.

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Contact details

Moritz Gold
Überlandstrasse 133
8600 Dübendorf, Switzerland
Tel: +41 58 765 5015
moritz.gold@eawag.ch
www.sandec.ch

Seydou Niang
Université Cheikh Anta Diop – LATEU/IFAN
BP 206, Dakar, Senegal
Tel: +221 33 825 04 11
seydou.niang@ucad.edu.sn
www.ucad.sn