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A socio-economic analysis of different approaches to faecal sludge treatment in Sunyani, Ghana

A. Mallory, M. Crapper, S.F. Gyasi & B. Boamah (UK)

REFEREED PAPER

With the SDGs moving beyond the focus on household sanitation facilities and aiming to halve the proportion of untreated wastewater and increase recycling and safe reuse, there is a need to look at new approaches to treatment. This study was conducted to investigate the socio-economic case for a resource recovery-based business model to fund faecal sludge treatment in Sunyani, Ghana. Semi-structured interviews were conducted with stakeholders including households, sanitation businesses and potential resource customers; together with observation and infrastructure mapping to assess the existing sanitation infrastructure and different options that could be implemented. Of the different resource recovery models investigated, biogas was the most acceptable option to customers whilst also providing a good business model to fund faecal sludge treatment, either as a decentralised system at public toilets where the fresh sludge is better for biogas production, or centrally at the existing disposal site.

Introduction

According to the Ghanaian government's own report (MLGRD, 2010), the level of faecal sludge treatment throughout all regions of the country is 'abysmal' with only 7 of 44 treatment plants functioning. There are often difficulties operating and maintaining technologies, with treatment plants in Accra and Kumasi breaking down due to component failure and poor maintenance, showing the need for new approaches to faecal sludge treatment. The government report places an emphasis on robust low-cost technologies that can handle the high BOD of faecal sludge from public toilets such as those often used by low-income communities. Even with simpler technologies there is a need for ongoing maintenance costs to be covered. The objective of this research was to assess the potential for different resources to be generated from faecal sludge treatment as a business model, and which of the options might provide the best profit incentive for long term management.

Method

A case study strategy was adopted to assess different options for faecal sludge treatment. Sunyani, a city located 125km North-West of Kumasi was chosen as the research location. It was chosen due to the limited level of existing research looking at faecal sludge management (FSM), the presence of a university for research support and its relatively small size, with a population of 125,000 in 2010 (Ghana Statistical Service, 2014). A city with limited information was chosen for the research to provide information about how treatment could operate in a different context with different stakeholders from the existing literature. The city's smaller size also means reduced distances and fewer informal, unplanned areas, making the FSM chain easier to manage up to treatment, providing a better environment for treatment than larger cities.

Mixed Methods were used to assess the possible different business models in Sunyani. Observation of vacuum truck driving routes, structured interviews with public toilet operators and infrastructure mapping were used to understand the existing infrastructure and identify businesses and stakeholders to speak to. Semi-structured interviews were then used to assess the acceptability and profitability of different resource options and how they would fit with the existing infrastructure and providers. Potential customers were asked about the competitor products they used and why, how they would approach any new product, and concerns they would have about waste based resources. The different interviewees are shown in table 1.

Household interviews were conducted in two different areas of Sunyani. Odumase, the first area, is a small town on the outskirts, about 9km from the disposal point, so it was chosen to study the possibility of decentralised treatment. Due to Sunyani's size it has less of a class division between areas than in the larger

Ghanaian cities like Kumasi and Accra, so a central area proximate to identified public toilets and gas filling stations was chosen as the second study area for household interviews, shown in figure 1. Two farming villages were chosen for farmer interviews. Wasasua is made up of farmers mostly from Sunyani area who owned the land they farmed, whilst Jato Nkwanta is mainly made up of migrants from the northern regions who farmed the land and gave a share of the produce to the owners.

Table 1. Interviews Conducted in Sunyani

Interview Type	Purpose	Number of Interviews Conducted
Stakeholder Interview	Understand existing sanitation level and challenges in Sunyani	11
Household Interview	Understand satisfaction with existing sanitation and perceptions of biogas and tilapia resource products	34
Farmer Interview	Understand perceptions of fertiliser resource product	30
Fish Farmer Interview	Understand perceptions of fish-feed resource product	4
Business Interview	Understand private-sector engagement in sanitation and economics and challenges of businesses	11

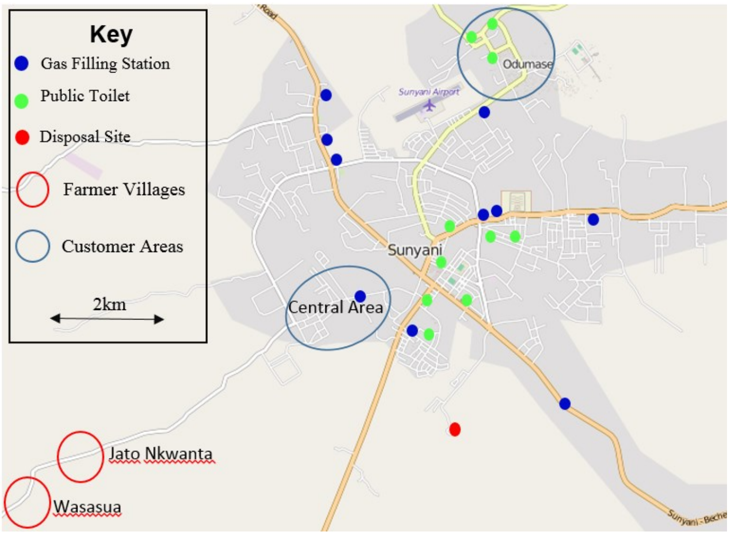

Figure 1. Infrastructure Map of Sunyani and Study Areas

Source: Map Data: © OpenStreetMap contributors

Results

Infrastructure Level

In terms of sanitation facilities, people use a mix of public and private toilets. There are 15 toilets that were surveyed and mapped within the municipality, shown in figure 1. There are 33 facilities in total but some of these were further away from the centre so were more difficult to visit. In addition to the Assembly (local government), there are two main companies who operate vacuum trucks for emptying toilets. The prison service, fire service and local polytechnic also have their own vacuum truck mainly for their own services rather than as a business. Solid and liquid waste is dumped at the same place. The road to the treatment site is currently very badly surfaced, is unusable during heavy rains and often causes trucks to get stuck.

The disposal site consists of a series of 6 treatment ponds that are no longer functioning. There are inefficiencies in funding management as dumping fees, 20 Cedis (1 Cedi=$3.81) per disposal, go straight to the Assembly budget, meaning they cannot easily be accessed for maintenance. This was clear when waiting a week for observation with the Assembly vacuum truck, as the truck crew were waiting for funds for fuel. This issue with finance and maintenance has led to the ponds becoming defunct and requiring large funds, 20,000 Cedis at the manager's estimate, to restore.

If restored the ponds could provide a basis for a resource-oriented business model, either by growing aquatic plants such as duckweed, or rearing fish directly in the ponds. The 15 acres of Assembly land at the disposal site could alternatively be used for a central biogas plant or composting plant to provide a model centred on biogas and fertiliser generation respectively. These four different resource options are investigated in semi-structured interviews based on their suitability to the existing infrastructure in Sunyani.

Resource Acceptance

Biogas

Biogas was the most well-known of the resources investigated in this study, with 14 of the 34 interviewees having some knowledge of the concept of biogas in discussions. It was also the resource in which the people responsible for sanitation in Sunyani were most interested and were hoping to produce. When the method of production was explained, most were open to the idea of using biogas as long as it was competitively priced.

There were some differences between customers in Odumase and town with regard to biogas. Firstly people in town mostly used liquefied petroleum gas (LPG) for cooking whilst those in Odumase used coal or wood, citing the expense of gas as prohibitive to buying. This is likely due to the upfront cost of canisters which started at 100 Cedis, enough to buy three months' coal. This means there might be marketing and innovative approaches required to replace coal and wood with biogas in Odumase and other lower income areas, whereas people in town who already use LPG are an easier market to access.

Cost was a large consideration for all interviewees when asked about using new fuels, with one interviewee saying *'We Ghanaians ....like cheap things. So if they introduce that one and it costs less ... I think people will buy'*. In Odumase there was generally less openness to the idea of biogas with health concerns cited more often than in town. The public toilets had a widespread reputation in Odumase for spreading the disease 'whites', or candidiasis, which people believed was caused by heat rising from the toilets. This meant people in Odumase were less open to the idea of using biogas, though some still would, with one interviewee saying *'our food is grown with the faeces anyway'*. In town there were fewer concerns about health and more about practicalities of use. When asked what they would do if they were offered a new type of fuel when refilling a canister some people said *'I would need someone to explain to me how to use it, how long it would last, and how long it works if I was to buy it.'* While others said that they would simply buy the new type and test it and compare it to the old.

Duckweed

Duckweed can be used as fish-feed, and can be grown on the surface of waste stabilisation ponds (WSP) for resource recovery (Hnoukpe Wendeou et al 2013). There is an association of 25 fish farmers growing tilapia in the surrounding area around Sunyani, who currently buy their fish-feed in Sunyani market. The four fish farmers interviewed all took their feeding advice from the fisheries department of the local government, so any decision to use duckweed would depend on advice from them. One fish farmer already used duckweed as a supplement as it grew on his fish pond and *'I came to the regional boss and told him about it and he encouraged me to keep it because before it was so much on the pond.'* when others were asked about the possibility of using new feed they would respond *'If we find a new one and the minister approves it, if it's approved then we will go and buy it. Until they ask us to buy I can't buy any food.'* One fish farmer was not keen on the idea as she had had to remove it from her own pond to prevent it affecting the water quality and damaging her fish, which can happen with a full cover of duckweed inhibiting oxygen diffusion and light penetration (Iqbal, 1999). Overall, for duckweed to be viable it would need to be done through the fisheries department who were open to the idea if they had *'information and background as to what duckweed can do… using duckweed and the results that they had using duckweed specifically maybe on tilapia.'*

Tilapia

Rearing Tilapia directly in the tertiary ponds and selling to customers at the market was another option that can be more profitable than duckweed growing (Iqbal, 1999). This was the least acceptable option to people in the area as a waste-based resource. People made comments such as *'the ones in the sea sometimes people ease their selves so I don't eat fish.'* or *'I have eased myself and now going to throw it away so if growing tilapia I wouldn't buy'.* There was one interviewee from the Fanti region who was open to the idea as *'where I come from they have sea and sometimes when we swim and when the waste is taken it is dropped in the sea so I know it happens.'* but otherwise it was not acceptable to people. Perhaps with community education it would be possible but the visceral opinions mean that it would be better to investigate alternative resources.

Fertiliser

The idea of using excreta as a fertiliser was one well known in both villages when asked about the possibility of using in interviews, with people often having heard about it through word of mouth and as one said *'that's an old technology so farmers have used cow dung before and it made crops grow faster.'* The use of animal droppings on farms was quite common, particularly with those who raised their own animals, but some also borrowed from farmers as shown by the following interviews: *'I know I already have 3.5 acres where I apply faeces from poultry so I know it is good.', 'there is no money to buy the fertiliser so sometimes I go to the poultry farming and ask for droppings to apply to crops.'* The latter interviewee also highlights the issue of cost of fertiliser, particularly in Jato Nkwanta where the farmers were of lower income and did not own the land. They did not use fertiliser because: *'There is no money to buy the fertiliser so I just do it like that', 'My desire is to buy fertiliser but I don't have the money.'* A few farmers in Jato Nkwanta also cited issues with the landowner as to why they did not use fertiliser: *'the problem is still that the owner needs to share the costs for the fertiliser. If I buy my own I will be cheated.'*

The people who used fertiliser were open to the idea of using fertiliser from treated faecal sludge. Their decision-making varied: for some *'The person (selling) is able to explain it well, how it functions, how it works then I would purchase one and see if it works well…. or if my brother bought some then I would follow and have a look'* or some who would *'try it and see the difference between the latter and the former.'*

Resource Production and Distribution

Biogas

Production of biogas would require construction and operation of a new biogas plant, which could either be done centrally at the disposal point or at public toilets, which are more suitable for biogas as it has stabilised less than latrine sludge (Strande et al 2014). Speaking to an academic at University of Energy and Natural Resources (UENR) in charge of the campus digester estimated a yield of 1.33litres/person.d so a toilet used by 300 people a day, which was typical in Sunyani, could expect to produce 146m^3/yr of biogas. The total waste in Sunyani is not known, but assuming that all 33 toilets have a similar rate of use there is a potential production of 4818m^3/yr. Based on a rate of 24-44litres/person.d (Colon et al 2015), a public toilet with 300 people a day would produce 2628-4818m^3 a year of biogas or 86700-159000m^3 a year across all toilets.

Currently people buy gas at filling stations throughout Sunyani shown in Figure 1. These have a similar distribution through Sunyani as the public toilets, so producing biogas and selling directly at public toilets is likely to be as accessible. If it was produced centrally it would likely need to be distributed to vending points in the city, which would raise issues due to the road condition.

Duckweed

Duckweed growth on the final ponds of treatment systems can yield around 20 t/h.yr (Iqbal, 1999). From satellite images, the three tertiary ponds have a total area of 736m^2 or 0.0736hectare, which could grow 1.47 tonnes a year. Currently fish farmers come from different surrounding towns and villages to buy prepared feed. If the duckweed is dried and pelleted it could also be sold prepared at local markets. Selling fresh would require regular distribution as fresh duckweed only lasts 3 days if kept cool and damp (Iqbal, 1999).

Tilapia

In a waste based rearing system it is possible to rear the fish tilapia at a yield of 6.7t/h.yr (Iqbal, 1999). This provides a yield of 493kg of fish per year from the tertiary ponds. Another business tried waste-based catfish rearing at densities of 4.72 and 2/m^2 (private communication). Using the lower estimate of 2/m^2 and a growth period of 6 months would yield 2944 fish/year, or 981.33kg/year assuming a fish size of 0.33kg which was the standard sale size at fish farms in Sunyani.

Fertiliser
Dried faecal sludge could be sold directly to farmers as a soil amendment at markets in Sunyani. Assuming a solids content of 35g/l (Diener, et al., 2014) and 216m^3 a year of faecal sludge from public toilets based on emptying frequency of once a fortnight that was given by public toilet owners, there is a total solids content of 7.56t/yr at a public toilet if sold directly there or 250 tonnes per year from all 33 toilets.

Economic Comparison

Biogas
LPG, the main competitor to biogas, is currently sold at filling stations for 1.72 Cedis per litre. Based on the estimate from the UENR academic (private communication) that biogas will last half as long a sales price of 0.86 Cedis per litre is assumed. This would yield annual sales of 125,560 Cedis scaling up from the university toilet, and 2.26-4.14 million Cedis per year using the experimental production. Across all public toilets, revenues of 4.14 million and 74.58-136.62 million Cedis could be generated. The higher estimates of production may be more than the existing gas market in Sunyani. Only 2 filling stations had information about LPG sales for cooking, with estimated sales of 456m^3 and 294m^3 a year, or 912m^3 and 588m^3 biogas equivalent. If surplus was produced it could either be scrubbed for car use, with many cars already using LPG, or a marketing strategy for replacing wood and coal could be developed. Capital investment estimates for a single public toilet digester varied significantly, with the UENR academic estimating 150,000-190,000 Cedis (private communication) while a public toilet owner had been proposed to build a biogas digester for 50,000 Cedis. Operating the digesters would require at least one member of skilled staff. The varying costs and revenues suggest that a pilot would be important to understand the actual economic case for biogas.

Duckweed
Ranaan is the only source of complete fish feed sold in Sunyani, at a price of 80 Cedis for a 20kg bag. Duckweed would need to be sold in combination with a high carbohydrate source such as wheatbran to provide the full diet for tilapia. At 4 Cedis per kg a yearly revenue of 6,000 Cedis could be generated. In terms of capital cost the main expense is tied up in desilting and restoring the treatment ponds which was estimated at a cost of 20,000 Cedis by the manager of the site who was applying for funds. Other than that, staff would be required for pond maintenance and collecting the duckweed as it is highly labour intensive compared to standard WSP operation (Iqbal, 1999). There would also be fuel costs associated with the regular transport of the product if sold fresh.

Fish
At a sales price of around 12 Cedis per kg when the fish weigh 0.33 kg, annual tilapia sales could generate 5,916-11,775 Cedis. The capital costs would be the same as the duckweed with the main requirement being to restore the pond and maintain operation with staff. There are also capital costs associated with buying the initial stocking fish. Operation would again require staff, and possibly supplementary feed.

Fertiliser
As there is little market for faecal sludge as an agricultural product, it is hard to estimate the sale price that could be generated. With the use of poultry droppings it was often on a charitable basis between farmers without cash exchange so sales of $4/ton, or 15.2 Cedi/ton, are assumed based on other African cities (Diener, et al., 2014). All the sludge from 1 public toilet could be sold at 114 Cedis per year, or 3800 Cedis for all public toilets. As biogas production is expected to leave only around 17% of the total solids to be sold as fertiliser (Diener, et al., 2014), this equates to potential supplementary revenues of 20 Cedis per year or 646 Cedis per year for 1 and all public toilets respectively.

Institutional Arrangement
Whilst there is a social acceptance for a profitable business model centred on resource recovery from waste treatment, there would need to be a suitable institutional arrangement implemented for the profit driver to encourage uptake of such a business model. When discussing the possibility with one stakeholder it was clear *'In its current state it is not of interest to businesses as the fees for collection combined with the dumping fees are not economical to fund treatment of waste.'* From the managers of treatment within Sunyani this opinion was also shared that there are *'not enough staff no. one person at the disposal site but it's not enough to maintain. If independent would be able to keep budget and operate independently.'* So for a resource-oriented

business model to be implemented in Sunyani there would need to be a change from the current institutional management to provide a profit incentive for resource recovery to be managed properly. This could either be done by setting up an independent company within the Assembly with profits passed to the Assembly or through contracting the management of the treatment plant.

Reflexivity

The issue of reflexivity has to be considered with the results, particularly relating to social acceptance and demand for different resources. Often the researcher's position as a comparatively wealthy European seemed to influence the results, as often people had the perception that the purpose of the research was to build a biogas digester/composting site for the community. This was particularly prevalent in the farming communities where while someone was being interviewed saying they do not use fertiliser a friend came in and said they '*should agree more as it is an NGO who may give some.*' A similar issue often arose when discussing biogas and people would ask *'are you going to build?'* However, the fact that interviewees still almost unanimously rejected the idea of tilapia shows that the survey was not completely answered based on trying to please the interviewer, and most of the time people expressed conditions for buying.

Conclusion

This research aimed to assess which resource-based faecal sludge treatment models could provide the best profit driver to fund ongoing treatment in Sunyani, Ghana. A satisfactory demand and acceptability of waste-based fertiliser, fish feed and biogas was identified whilst waste-reared tilapia did not have market demand so would not function. Of the three different possible resource based models biogas has the largest profit driver, even based upon the lower estimate of the digester production at UENR. To fully assess the potential profit, better data would be needed on the quantity and quality of sludge in Sunyani, and for environmental reasons a treatment plan for the remaining sludge after resource recovery would be needed.

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Contact details

About the author: Adrian Mallory is a PhD candidate at the University of Edinburgh with an interest in faecal sludge management and Human Centred Design.

Adrian Mallory
Kings Buildings, University of Edinburgh
a.mallory@ed.ac.uk

Professor. Martin Crapper
University of Northumbria, Ellison Place,
Newcastle Upon Tyne, NE1 8ST
Martin.Crapper@northumbria.ac.uk