CASE STUDIES

Faecal Sludge Management in Lusaka, Zambia

Alison Parker, Peter Cruddas and Chris Rose


PHOTO: A toilet pit emptying team at work in Lusaka. Chris Rose.

GDEE GLOBAL DIMENSION IN ENGINEERING EDUCATION

CASE STUDIES **Faecal Sludge Management in Lusaka, Zambia**

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FAECAL SLUDGE MANAGEMENT IN LUSAKA, ZAMBIA

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1. INTRODUCTION

The Global Dimension in Engineering Education (GDEE) is a European Union funded initiative involving a collaboration of development NGOs and Universities, with an aim to integrate sustainable human development as a regular part of all technical university courses. Part of the initiative is the development of a set of case studies based on real field experiences of development projects. The case studies cover a broad range of topics directly related those studied in engineering, science and other technology/environment/development-related courses.

This case study examines issues surrounding the management of faecal sludge, using Lusaka in Zambia as a case example. 2.5 billion people on our planet still lack access to improved sanitation – they have nowhere safe to go to the toilet (WHO and UNICEF 2014). Instead, they defecate in the open, use a “flying toilet” (a plastic bag which is thrown away), or use a communal toilet. These options are unhygienic, undignified and present particular risks for women. In rural areas people can build simple pit latrines and install a hygienic slab on top which keeps it safe. When the pit fills up they just cover it up and dig a new one elsewhere. But in urban areas with high population densities, this is not an option. In many unplanned settlements and even in some planned ones there is no sewerage. Across the world, forward thinking municipalities, NGOs and entrepreneurs are trialling systems to provide safe sanitation in low income urban areas. This case study highlights the work which the non-profit partnership organisation, Water and Sanitation for the Urban Poor (WSUP), are doing in an area called Kanyama in Lusaka, Zambia. They are training pit latrine emptiers in hygienic practices, treating the waste they collect and transforming it into useful products. They are developing a sustainable business model which can be used elsewhere in Lusaka and across the world.

1.1. DISCIPLINES COVERED

Sanitation is a multi-disciplinary topic and the majority of this case study could be used across a range of disciplines including engineering, design, environmental science, business, social science, public health and international development. The class activity included covers the technical aspects of an anaerobic digester design so would be suitable for students of environmental engineering, chemical engineering, process engineering, or any other course that covers wastewater treatment. However, for non-engineering students, the class activity could be omitted, making the case study suitable for a wide range of disciplines. In fact, the global sanitation crisis will not be solved unless it is addressed by experts from across the disciplinary spectrum.

1.2. Learning outcomes

As a result of this case study, students are expected to be able to:

- Understand the challenges in providing sanitation in low income urban areas
- Design an anaerobic digester for pit latrine waste
- Understand some possible alternatives to pit latrines.

1.3. Activities

Class Activity: designing an anaerobic digester for pit latrine waste like the one WSUP have built. The students are given the principles for designing the digester together with the parameters of typical pit latrine waste and background context for the case study. From this information they will be required to design a suitable digester based on the population served, waste characteristics, and ambient temperature. They will also be required to estimate the amount of biogas produced and the frequency and amount of waste digestate that would need to be withdrawn from the digester.

Homework Activity: students research alternatives to pit latrines and write a four page brief on one of the alternatives. This activity could be completed as individuals or groups. If the internet was not available for research then material from selected systems could be provided to the students for them to synthesize into the brief.

2. Description of the context

Figure 1: *Flooding in Kanyama (photo T. Heath)*

Kanyama is an informal settlement in the South East of Lusaka. It has a population of around 250,000 (Drabble 2014). It is very flat and rocky and is the natural drainage plain for the city; as a result it experiences severe flooding (see figure 1). This is a common scenario as low income urban residents are often forced to build their homes on marginal land like floodplains, steep slopes or railway embankments. Water is supplied by community cooperatives (Water Trusts), using boreholes and kiosks (see figure 2) that are licensed by the city's main water utility

(Heath et al 2012), although some residents collect water from shallow wells, particularly for non-consumptive uses like washing clothes. Sanitation is predominantly (90%) pit latrines, 85% of which have never been emptied (Drabble 2014). This causes problems in the rainy season as floodwater causes the latrines to overflow: their contents are washed onto the street (Heath et al 2012). If pits are emptied, the waste is simply moved to another location nearby, rather than being removed altogether (Alexander et al, 2013).

The obvious consequence of this is on health. As well as the usual diarrhoeal diseases associated with poor sanitation, Lusaka also has an annual cholera outbreak, with 5,600 cases and 120 deaths in the low income parts of Lusaka every year (UNICEF, n.d.). Poor sanitation affects nutrition, specifically people's ability to absorb nutrients too. Overall this has a knock-on effect on education and income generation: if children are ill they will miss school; if adults are ill they will not be earning money as 90% of workers are in the informal sector (World Bank 2002) and have no sick pay. Women tend to be disproportionately affected. If their own household latrine is full and they are looking elsewhere for somewhere to go to the toilet they may be out late at night when they are at risk of rape. The residents on Kanyama have the right to dignified sanitation.

Figure 2: *Water kiosk in Kanyama*

2.1. The pit emptying teams

WSUP decided to help address this problem. Their first task was to set up a formal, hygienic and affordable pit emptying system. There were already some informal pit emptiers in Lusaka. In early 2013, ten of them were hired and trained. Initially it was hoped that manually powered mechanised devices like the gulper could be used to empty pits (Mikhael and Drabble 2014). However, because the pit latrines

Figure 3: *The Dream Team in action*

contained a lot of solid waste ("trash/rubbish") – on average 12% (Rose et al, in preparation) it was necessary to use a long handled shovel to empty the pits (Mikhael and Drabble 2014). The emptying teams are supplied with personal protective equipment to protect their health, as well as uniforms to make them identifiable and give them some self-esteem – pit emptying is often seen as a taboo activity. The pit emptying team are marketed as the "Dream Team" (see figure 3) (Mikhael and Drabble 2014).

2.2. Economics and management

During the initial market research, WSUP discovered that people found existing pit emptying services too expensive (Alexander et al, 2013). An alternative was to only empty the top part of the latrine and charge people a lower price for this service. As such, three levels of service are offered: 12 60-litre drums for US$40; 24 drums for US$60; and 32 drums for US$70. Landlords go to the Water trust office and pay for the service in advance; the Dream Team then empty the agreed number of drums on the agreed date (Mikhael and Drabble 2014).

2.3. Waste treatment

Figure 4: *The anaerobic digester*

The drums are then washed down and transported by hand cart to an anaerobic digester (see figure 4) which is less than 3km away from all the pit latrines. This is currently the "bottle-neck" of the process, and more hand carts are being acquired to make the emptying more efficient. It is not possible to use trucks as these could not get to every latrine, and the time saving would be so marginal that it would not justify the capital and operating expense.

After initial screening to remove the solid waste, the pit waste enters the digester. Anaerobic digestion is a series of microbiological processes that occur in the absence of oxygen:

1. Hydrolysis -insoluble particles are converted to soluble derivatives that become available for other bacteria.
2. Acidogenic – bacteria convert the sugars and amino acids into carbon dioxide, hydrogen, ammonia, and organic acids and onwards into acetic acid, along with additional ammonia, hydrogen, and carbon dioxide.
3. Methanogenesis - the conversion of these products to methane and carbon dioxide.

Overall, both the solid and pathogen content is reduced (Tchobanoglous et al 2003).

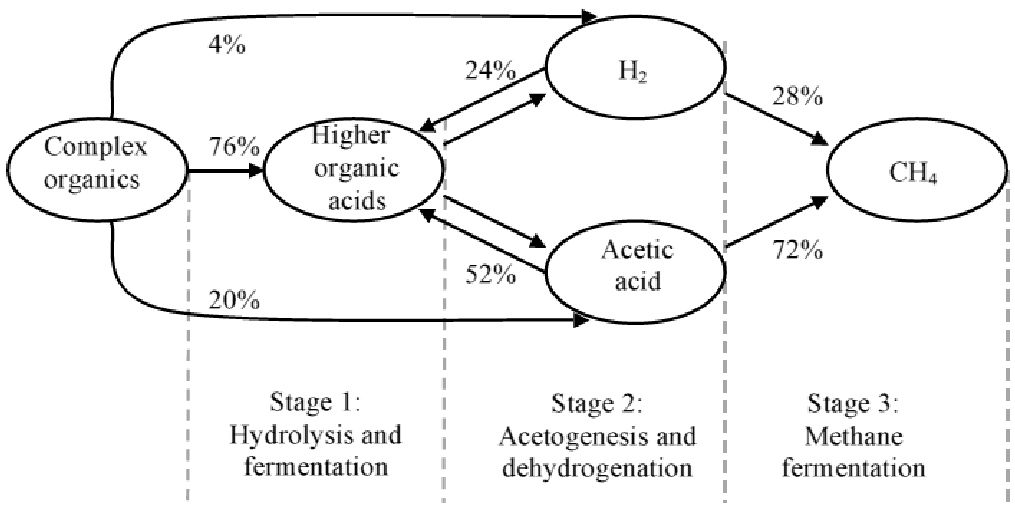

Figure 5: *Steps in methane production from human waste. (Source: Tchobanoglous and Schroeder, 1987)*

This digestion is producing biogas which is used for cooking in the Water Trust canteen which is next to the digester. (Mikhael and Drabble 2014). However, gas production from pit latrine waste is limited compared to fresh waste produced from anaerobic digestion, with the biogas escaping to the atmosphere (Rose et al 2014). The solids left over are transported to drying beds. UV in the sunlight kills the remaining pathogens, and the solids are further dried. The ultimate aim is to sell this as fertilizer (Drabble 2014). The remaining liquid which still contains nutrients like phosphorous, potassium and nitrogen is discharged onto a planted gravel filter which grows bananas (Kellner 2013).

2.4. Outcome to date

By June 2014, after 500 days' of operation nearly 700 pits have been emptied, serving approximately 10,000 people, and with nearly 500m^3 of sludge removed (Mikhael and Drabble 2014).

3. Class activity

3.1. Methodology

The class activity will focus on the design and operation of an anaerobic digester. The class will be briefed for 15 minutes with the background information in section 3.2, and will then be split into groups to design a suitable digester for the task. The groups will be given one hour to complete the task, after which they will be required to give a five minute presentation of their design to the class. The final 30 minutes will involve a discussion of any differences in designs, and for the lecturer to clarify any questions that arise from the task.

3.2. Class activity description

The class should be given the following briefing:

"Due to the success of the Dream Team model, WSUP have decided to expand the operation, which will include installing a new digester to receive the increased amounts of waste to be collected. The new scheme is expected to empty two pits a day with the waste brought to the new digester. WSUP have advised that the average volume of sludge emptied from one pit is 1.5 m^3, with an average total solids (TS) content of 16 % weight/weight and density of 1,300 kg/m^3. As an extension of the existing project, the digester will be based in Lusaka, which has a mean monthly low temperature of 7^oC in the winter, a high of 29^oC in the summer, and an annual mean of 20^oC (NOAA, 2012).

Your group has been tasked with the design of the new digester, which should be appropriate for the case study described and include:

- the size of the digester and holding chamber for the biogas
- an estimation of the amount of biogas to be produced

Your group will be required to submit the design calculations on paper with a clear and neat method, and give a short 5 minute presentation to explain the rationale behind the design chosen."

The following design information is provided for consideration:

Recommended solids retention time (SRT) for unmixed digesters are shown in figure 5, where:

$$SRT\ (in\ days) = \frac{Volume\ of\ digester\ (in\ m^3)}{Flow\ rate\ of\ sludge\ introducted\ (in\ m^3 per\ day)}$$

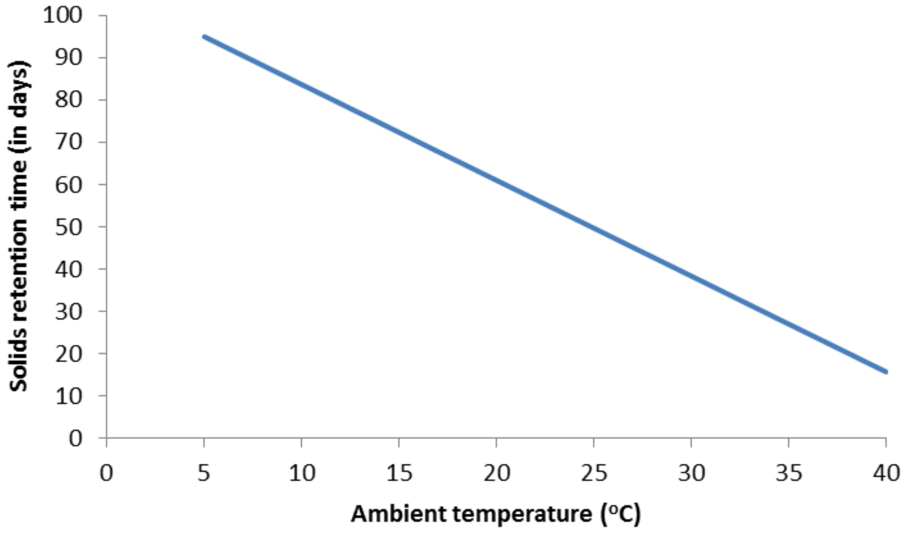

Figure 6: *Recommended safe solids retention time (SRT) for unmixed digesters*

Expected biogas yields for pit latrine waste in unmixed digesters is 0.04405 m^3/kg TS introduced (Rose et al 2014).

3.3. Solution and evaluation criteria

Evaluation of the class activity will be in two parts – examination of the written calculations against the model solution provided, and assessment of the justification for the design given during the presentation.

Model solution:

The design SRT should be decided based on the minimum operating temperature of the digester. The minimum temperature could be taken from 7^{o}C as an absolute minimum up to 15^{o}C as an absolute maximum if the students were to consider insulation of the digester, either by surrounding ground if it was buried or through the digester itself. Any temperature selected within the 7 to 15^{o}C range would be acceptable but extra marks should be given for consideration of insulating the digester to improve performance and safeguard against extreme temperatures. A recommended safe minimum operating temperature from the data given would be 10^{o}C, which from reading off the graph (figure 6) would give an SRT of 85 days.

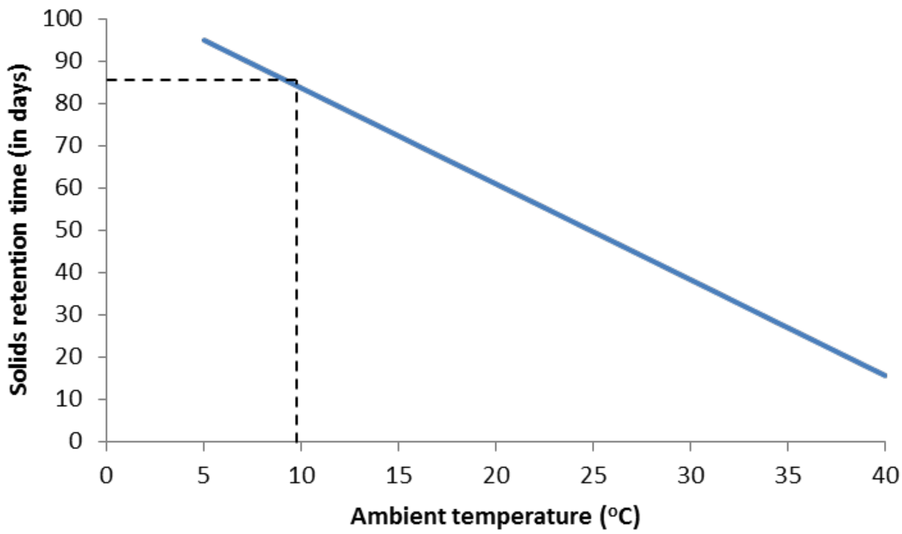

Figure 7: *85 days is the SRT for a digester running at 10^{o}C*

An SRT of between 70 and 90 days would be permissible in the students' calculations, and justification for selecting a design temperature, and therefore SRT, should be expected.

With two latrines expected per day at 1.5 m^3 each, the design flow rate is 3 m^3/day.

The equation given for SRT should then be rearranged to make volume the subject:

$$SRT = \frac{Volume}{Flow} \quad \text{therefore} \quad Volume = SRT \times Flow$$

With an SRT of 85 days, and a flow rate of 3 m^3/day, the volume of the digester calculated from the equation given would be: 85 x 3 = **255 m^3 digester volume**.

The daily sludge loading rate is 3 m^3/day with a TS content of 16 % weight/weight.
3 m^3 of sludge at density 1,300 kg/m^3: 3 x 1300 = 3,900 kg/day
3,900 x 16 % = 624 kg TS/day

With an expected biogas yield of 0.04405 m^3/kg TS introduced:

624 x 0.04405 =**27.4872 m^3/day of biogas produced.**

The mean yield will fluctuate seasonally with change in temperature and extra marks should be given to groups who make this observation.

4. Homework activity

The homework activity should be introduced by asking the students to think about the disadvantages of the current system in Lusaka, and contribute their answers in a group discussion. Points could include:

- Pit latrines can pollute shallow groundwater, which is still used as a water source.
- There is some spillage into people's yards during the pit emptying process (see slide 5).
- Even with PPE pit emptiers still face health risks and stigma.
- Not all the biogas is captured – a large proportion escapes to the atmosphere form the pit latrines.
- The fertiliser sales have not yet been proven.
- The planted gravel filters may be being overloaded (see slide 11).
- $40 is a lot for a one-off payment

Give the students the following brief:

"Kanyama Water Trust would like to try an alternative sanitation system. They are interested in a system that:

- Protects the environment and people's health
- Maximises the value of the energy and nutrients in the waste
- Is affordable to their customers without requiring any subsidy
- Has been piloted in a similar location already

Research and compile a four-page brief on an alternative system, explaining how it is well suited to work effectively in Kanyama. If you cannot find a system that meets all of the Waters Trust's requirements justify why you think your chosen option is the best compromise."

4.1. Solution and evaluation criteria

The selected systems should meet the criteria above, but the reality is that this is a relatively new area of development and most promising systems are still under trial. The following are some questions against which to evaluate the selected solution:

Does the proposed system:

- provide treatment of all the waste (both the liquid and solid components) to an appropriate standard?
- provide hygienic separation of users from their faeces?
- protect workers' health?
- capture energy and/or nutrients in a way that is
  - acceptable to the end users of the products?
  - cost-effective?
  - scientifically proven?
- have a proven business model that includes
  - an affordable cost to households?
  - low operation and maintenance costs (including energy)?
  - a realistic assessment of the value of the energy and/or nutrient products?
- have a low footprint suitable for a dense urban area?
- operate without a sewer network?
- operate without additional water?

Students should show evidence that they have critically assessed their data sources. Documents from the developers of these systems may provide a biased evaluation. The following is a list of alternative faecal sludge management systems which the students could pick. It would also be possible to nominate these in advance to each group/individual if research time was limited.

- Clean Team http://www.cleanteamtoilets.com/
- Loowatt http://www.loowatt.com/
- SOIL http://www.oursoil.org/
- X-runner http://www.xrunner-venture.com/home/4583965215
- Sulabh http://www.sulabhinternational.org/content/two-pit-system
- Condominial sewerage e.g. http://www.wsp.org/sites/wsp.org/files/publications/BrasilFinal2.pdf
- DEWATS http://www.borda-net.org/dewats-service-packages.html
- Biofil http://www.biofilcom.org/
- Sanergy http://saner.gy/
- LaDePa e.g. http://www.susana.org/docs_ccbk/susana_download/2-1624-harrison.pdf

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FURTHER/SUGGESTED MATERIAL

- Using Biogas technology to solve pit latrine waste disposal problems, Practical Action Technical Brief http://www.engineeringforchange.org/static/content/Sanitation/S00039/Biogas%20pit%20latrine%20waste%20solution%20technical%20brief.pdf
- Disposal of latrine waste: Is biogas the answer? A review of literature. Daniel Buston and Brian Reed, Engineers Without Borders UK http://www.hedon.info/docs/EWB_ENERGY_Daniel_Buxton_and_Brian_Reed_Disposal_of_latrine_waste_Is_Biogas_the_answer.pdf
- Anaerobic Digestion: Principles and Practices for Biogas Systems. Charles Gunnerson and David Stuckey, World Bank Technical Paper No. 49 http://www-wds.worldbank.org/servlet/WDSContentServer/IW3P/IB/1999/11/19/000178830_98101904164835/Rendered/PDF/multi_page.pdf

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