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Optimizing biogas recovery from pit latrine faecal sludge

Presented By

P. Madikizela, R. Laubsher, R. Tandlich and N.P. Ngqwala

RHODES UNIVERSITY
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Introduction

- Pit latrines are the common cost effective sanitation facilities that are used for the collection, storage and treatment of excreta mostly in developing countries.
- Over time, these facilities fill up and the faecal sludge requires emptying, a task which is achieved by applying manual methods or mechanical methods [1-2] .
- After the pit emptying, faecal sludge is usually disposed in wastewater treatment plants, water bodies or in open fields.

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- Various techniques are available for treating faecal sludge and converting the organic content into a valuable resource and these include composting, anaerobic and aerobic digestion, vermicomposting, deep row entrenchment and solar drying [3-6].
- Anaerobic digestion (AD) is of interest because treatment process leads to the production of biogas and the sludge which could be used as a fertilizer or a soil amender.

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- A pH range of 6.8 to 7.8 is the recommended optimum range for AD, but the final pH varies depending on the digestion technique and the substrate [7].
- A wide range of temperatures is used for optimum AD which range from psychrophilic, mesophilic, thermophilic and hyper-thermophilic [8,7].
- For the optimum operation of the digester the ratio of carbon to nitrogen has to range between 20 to 30:1 [7].

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- High moisture content (90%) in sludges is known to increase methane production [9].
- In cases where methane production is low, pre-composting or thermal treatment is used to improve biogas yields [8,10].
- Extracellular enzymes such as proteinases, peptidases and lipases are used to enhance the breakdown of organic matter thereby improving methane production during AD [11- 12].

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- Small scale digesters are used to treat human waste in community healthcare centres, prisons, boarding schools and hospitals [10,13, 14-15].
- The use of biogas as a fuel in developing countries could potentially reduce deforestation, indoor pollution and also give women more time to partake in other activities other than collecting firewood for cooking [16].
- This study focused on optimizing the recovery of biogas from pit latrine faecal sludge with or without a co-feed using a simple anaerobic digester in order to reduce the possibility of pit latrines exceeding their retention capacity and causing sanitation-related health problems.

Materials and methods

- Three consecutive AD experiments were run at mesophilic temperatures (29 ± 2 degrees Celsius) in a controlled environment room.
- Faecal sludge was collected from Hlalani Township in Grahamstown.
- The potential sampling ventilated improved pit latrines (VIP) were selected based on accessibility and the least rubbish present in the pit to facilitate extraction of the pit contents.
- A coarse nylon mesh bag (mesh size ~ 1 centimetres) was used for the screening the pit latrine faecal sludge material prior anaerobic digestion.

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- A 2 metre long hollow steel (2 millimetres thick and 80 millimetres external diameter) corer was used to recover the contents of the pit latrine (see Figure I).
- Recovery of pit material was achieved by constantly rotating the corer until the bottom of the pit was reached.
- The collected material was transferred into 25 litre plastic buckets.
- The used faecal sludge recovery method was not repeated because it was very laborious and only permitted a recovery of limited amount of the faecal sludge.

Figure I: The hollow sampler that was used to collect the pit latrine faecal sludge on the first sampling expedition with the plastic cover sleeve next to it.

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- The initial AD experiment was run using a tall Perspex digester with an electric stirrer attached to the top and the inner car tyre tube (18 litres) was used for gas collection (see Figure II).
- The pit latrine faecal sludge (20 litres) collected from a single pit latrine was used as a feed stock without an inoculum.
- The sludge was homogenised using an electrical stirrer.
- The experiment was run for 60 days to improve biogas recovery.

Figure II: The Perspex digester used for anaerobically digesting pit latrine faecal sludge. An inner tube of a car tyre (white arrow) was attached to the top of the digester collected biogas.

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- A 2nd AD experiment was run using 3x 200 L plastic drums (see Figure III).
- The changes in the anaerobic digester design were to mitigate energy inputs into operating the AD and to improve biogas recovery.
- Pit latrine faecal sludge from multiple pit latrines was used as a feedstock and a co-feed sourced from the Belmont Valley Wastewater Works was added to two digesters.
- The mixing proportions in the two digesters were 1:2 (33% FS) pit latrine faecal sludge and the effluent from the anaerobic digester, 2:1 (66% FS) pit latrine faecal sludge and the effluent from the anaerobic digester.
- One digester had 100% of pit latrine faecal sludge and this served as a control.
- Each digester was filled to 180 L leaving 20 L headspace for gas collection.
- This experiment was run for 45 days, as this was considered sufficient time for biogas recovery [7].

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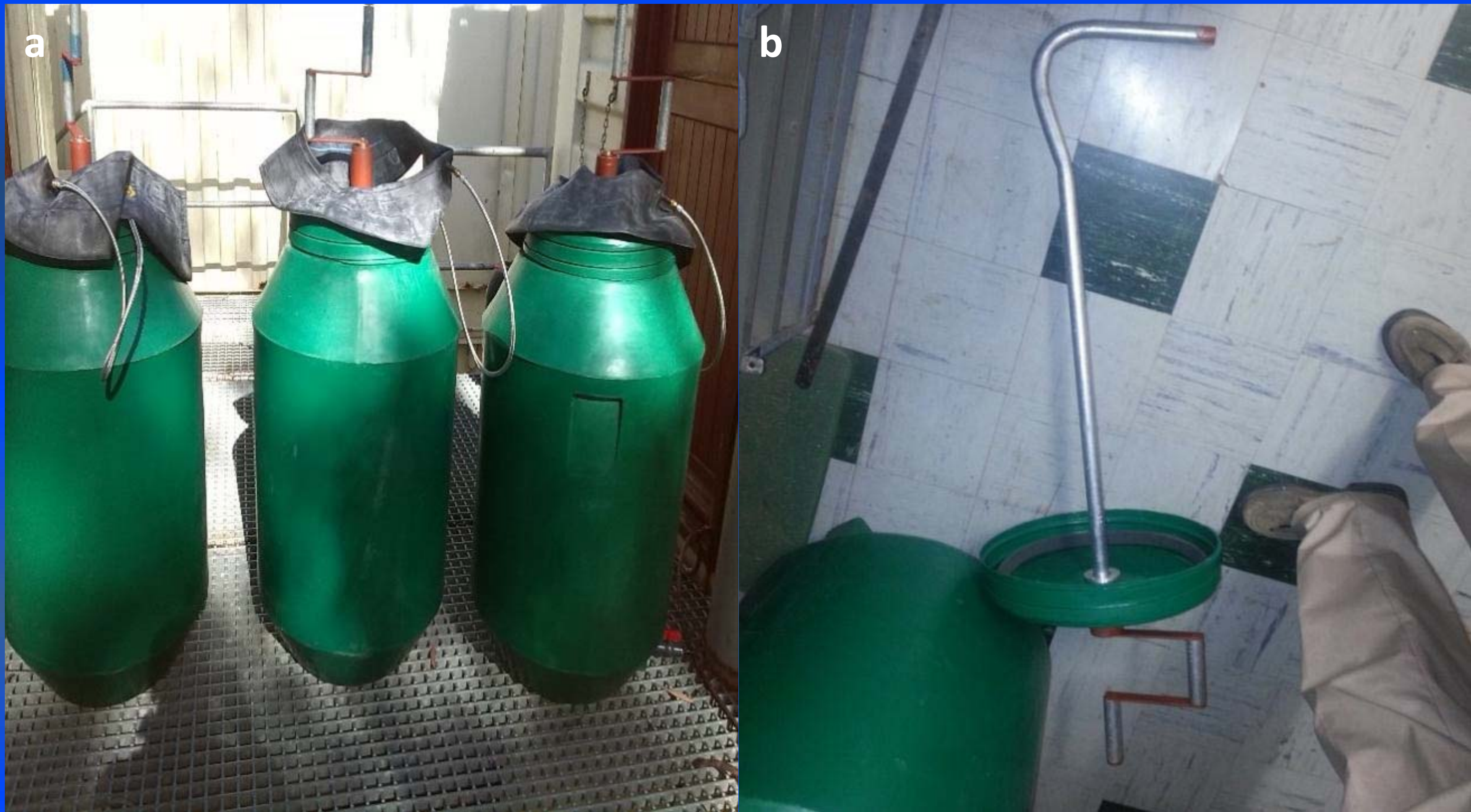

Figure III a: The second type of anaerobic digesters with the attached inner car tyre tube. **Figure III b**: The crank handle with the stirrer attached to the lid of the anaerobic digester. This was to permit stirring of the anaerobic digester contents.

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- A third AD experiment was conducted after the completion of this digestion experiment.
- To improve gas production, each digester was additionally inoculated with 2 kg of bovine paunch manure obtained from an abattoir near Grahamstown.
- The physiochemical and microbiological properties of the faecal sludge were analysed prior the AD.

Results and discussion

Table I. The physicochemical properties of the pit latrine faecal sludge before the first anaerobic digestion experiment.

Parameter	Measurements (n=3)
Dry weight % of wet weight (g/g)	92.8 ± 0.3
Moisture content (%) (g/g of dry weight)	7.2 ± 0.3
LOI % (g/g of dry weight)	96.1 ± 0.2
COD (mg/l)	1 406 ± 0.4
PO_4^{3-} (mg/l)	48.1 ± 3
NH_4^+ (mg/l)	10.9 ± 5
NO_3^- (mg/l)	26 ± 2
Cl^- (mg/l)	2 293 ± 95

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Table II. The physicochemical and microbiological properties of the pit latrine faecal sludge mixed with the effluent from the anaerobic digester of Belmont Valley WWTW at different ratios before anaerobic digestion.

Parameter	33% FS	66% FS	100% FS
Dry weight % of wet weight (g/g)	1.30 ± 0.30	2.79 ± 0.61	2.77 ± 0.30
Moisture content (%) of dry weight (g/g)	98.7 ± 0.3	97.2 ± 0.6	97.2 ± 0.3
LOI (%)of dry weight (g/g)	61.1 ± 10.1	77.1 ± 5.0	64.4 ± 0.1
COD (mg/l)	46 317 ± 12 872	43 580 ± 10 763	35 780 ± 3 935
PO_4^{3-} (mg/l)	103 ± 6	133 ± 23	137 ± 15
NH_4^+ (mg/l)	8 537 ± 3 575	7 600 ± 990	10 080 ± 439
NO_3^- (mg/l)	15 600 ± 3 524	24 277 ± 7 588	24 017 ± 6 985
K (mg/l)	670 ± 375	1 267 ± 35	553 ± 12
Cl^- (mg/l)	297 ± 91	350 ± 46	393 ± 86
pH	7.50	7.57	7.00
***E.coli* (cfu/g of dry weight)**	$7.5x10^2$	$3.7x10^3$	$6.6x10^2$
***Salmonella* spp. (cfu/g of dry weight)**	$7.5x10^2$	$3.7x10^2$	$3.3x10^2$
Total helminths/ g of dry weight	0	0	1

Results and discussion

Table III. The physicochemical and microbiological properties of the different proportions of pit latrine faecal sludge and the effluent from the WWTW mixed with cow paunch before the third anaerobic digestion experiment.

Parameter	33% FS	66% FS	100% FS
Dry weight % of wet weight (g/g)	2.12 ± 0.60	1.64 ± 0.60	0.82 ± 0.60
Moisture content (%) of dry weight (g/g)	97.9 ± 0.6	98.4 ± 0.6	99.2 ± 0.6
LOI (%)of dry weight (g/g)	57 ± 14	33 ± 29	0
COD (mg/l)	3 639 ± 87	3 216 ± 70	2 993 ± 66
PO_4^{3-} (mg/l)	82 ± 1	95 ± 7	99 ± 3
NH_4^+ (mg/l)	21 067 ± 5 041	18 673 ± 5 065	19 187 ± 1 123
NO_3^- (mg/l)	5 943 ± 178	5 533 ± 806	5 443 ± 525
K (mg/l)	313 ± 6	340 ± 10	427 ± 21
Cl^- (mg/l)	583 ± 11	590 ± 6	712 ± 22
pH	7.32	7.51	7.79
***E.coli* (cfu/g of dry weight)**	1.4×10^5	1.3×10^5	1.5×10^4
***Salmonella* spp. (cfu/g of dry weight)**	0	0	0
Total helminths/ g of dry weight	0	0	0

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Table IV: The biogas recovered from pit latrine faecal sludge.

Experiment	Digester content	Estimated biogas recovered (L)
AD1	100% FS	0
AD2	33% FS	18
	66% FS	0
	100% FS	0
AD3	33% FS	0
	66% FS	285
	100% FS	0

The volume of gas recovered was calculated using the following formula:

$$V(m^3) = 2\pi^2 \times Rr^2$$

V is the volume of the tyre, R is the centre of the torus (average of internal diameter and external diameter of the tyre) and r is the thickness of the tyre divided by 2.

Conclusion

- It is possible to recover biogas from pit latrine faecal sludge through anaerobic digestion, provided a co-feed is added.
- Recovering biogas from 100% pit latrine faecal sludge was not successful, possibly due to the stabilized nature of the bulk of the pit latrine faecal sludge, where the remaining organic content was less accessible to the anaerobic microbial consortia.
- This could lead to less organic material being available to contribute to methane production [17].

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