BIOGAS TECHNOLOGY FOR RURAL DEVELOPMENT IN ZIMBABWE

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ABSTRACT

This paper reports laboratory experiments of the anaerobic digestion of pigeon droppings and waste material from coffee processing and the application of these findings in field trials using three types of biogas digesters designed and built in Zimbabwe. It is concluded that biogas technology may be a feasible solution to the shortage of wood-fuel and fertiliser in the rural areas.

INTRODUCTION

Although biogas generation is already a well known technology in countries such as India and China, many people in Zimbabwe are not familiar with this technology. A biogas project, described in this paper, was launched to develop and promote biogas technologies for use in the rural areas of Zimbabwe through investigations into user needs, feedstock for biogas digesters and utilisation of the biogas and slurry.

LABORATORY WORK

Prior to initiating wide scale field trials, laboratory investigations were conducted to determine the amenability to anaerobic digestion, quality of gas produced (CH_4 content) and optimum pH, temperature and retention time for various potential substrates. The necessary modification of existing cooking and lighting appliances to operate on biogas has also been investigated.

Evaluation of the performance of biogas substrates

A crop residue, wastes from coffee production, and an animal waste product, pigeon droppings, were tested in a laboratory scale biogas digester. The digester was maintained at a constant temperature throughout. Total solids (TS), volatile solids (VS), fixed solids (FS) and volume of gas produced and pH of the slurry were measured.

Results

The biogas obtained from coffee wastes was almost odourless, indicating very little hydrogen sulphide. Gas from pigeon waste was fairly odorous.

Mixing of digester contents by occasional hand swirling, proved inadequate in the case of coffee waste which tended to froth and form a floating scum which at times rose and blocked the gas outlet.

An analysis of the substrate used is presented in Table 1 and the amount of gas produced over a 16 week period is presented in Table 2.

Discussion

Crop and animal waste produce biogas of slightly different composition. Gas chromatography would be necessary to determine the actual composition of the gas. A number of problems were encountered including the following:

a. There was difficulty in obtaining representative samples for total solids and volatile solids because of the heterogeneous particle size of the coffee waste. Because only small samples were collected, the presence of a large solid lump would raise the TS value obtained with that sample.

   Grit present in pigeon waste caused similar problems and had a marked effect on the weight of the ash left in the crucible when the VS had been driven off. In this case, it is advisable to collect the samples at a fixed time after swirling the digester.

b. The coffee waste particles trapped gas bubbles and were buoyed to the top of the slurry, leaving most of the liquid below. The particles were then slowly lifted by the gas from the liquid layer until they blocked the gas outlet. This tendency to float was countered by frequent stirring to release trapped gas bubbles.

c. There was a gradual build-up of grit at the bottom of the digester due to its presence in the pigeon waste. It was therefore found necessary to empty the digester and remove the grit occasionally.

Research on appliances

Household appliances in Zimbabwe are relatively crude and inefficient. Local manufacturers have concentrated on cookers for both high and low pressure bottled gas. Some high pressure gas lamps have also been manufactured. Work has been carried out to modify some of these appliances to use biogas.

Cookers

Most biogas cookers currently used in rural Zimbabwe do not include the pre-mixing of biogas with air. We investigated the performance of these cookers with and without pre-mixing of biogas. The advantages of pre-mixing are presented in Table 3.

Gas Lamps

The commercially available cadac gas lamp has a small jet and this does not allow gas to flow freely. The jet was enlarged to a diameter of just over 1mm to provide the required richer gas:air mixture. Gas delivered at a constant pressure of 10-20cm water column above atmospheric provided a steady flame. Undried gas gave only half the rated illumination of the lamp. Work is now being carried out to fabricate a low cost Indian-type biogas lamp.

FIELD TRIALS

Biogas technology was introduced to the rural people in the form of various demonstration digesters described in the following sections.

Oil drum digester

A 200 litre oil drum was filled with cow dung slurry and completely sealed leaving an outlet for the gas. The gas was stored in an inner tube obtained from a local bus company. A small tin stove was connected to the inner tube. This digester was used as a demonstration model at agricultural shows.

Domboshava biogas plant

This digester was based on an Indian design of fixed brick-lined digester. The pit was shallower because of the possibility of striking a high water table which would have cooled the sludge to some degree. The materials used to build the plant were as follows:

2500 fire burnt bricks	25 x 50kg packets of cement
230 metres (10 gauge) wire	35 metres (12mm) reinforcing rods
5 litres epoxy pitch black paint	6 metres (150mm int dia) asbestos P
3.8 metres (75mm) galvanised pipe	1.3 metres (100mm) galvanised pipe
1 gate valve	1 base plate
4 (100mm) bolts and nuts	1 gasometer tank
5 kg bittumen sealant	Hose pipe and clamps as required
5 litres aidpol	according to distance.

The digester was built within a few days and operated on sludge from one of Harare's sewage works. Enough gas was being produced within a week to provide for cooking in a nearby building and to run a refrigerator once the jet had been enlarged slightly. A caravan-type gas lamp did not work as satisfactorily as the cooker.

The gas produced contained: 69% methane; 21% carbon dioxide; and 10% nitrogen and other gases.

Gas production was measured during the day, during the night and between Friday evening and Monday morning (the weekend). Overall production and consumption in cubic metres are as follows:

	Produced	Consumed
Day	10,572	17,749
Night	5892	0
Weekend	4155	0

The average daily gas production was estimated to be 0.570 m^3 during winter days and $1.2m^3$ during summer days. About 7.5 kg of cow dung was fed into the digester every day except over the weekends. This gave gas production of $0.076m^3$ per kg in hot months.

Chishawasha biogas plant

This plant based on a Chinese design of $3m^3$ capacity was built for a family in the rural area near Harare. Materials used for the digester were as follows:

13 x 50kg cement	1 brass gate valve
	700 bricks
7 kg impermo (waterproofing compound)	1 x 50kg building lime
5 kg sealing putty	6.65 m galvanised pipe (20mm)

Local people were trained on site to build the digester. Difficulty was encountered in building the dome, which was shaped by using a pole with a flat board (approx 150 mm x 75 mm) perpendicular to its end. The total length of the pole from the bottom to the surface of the board was R mm which was the radius of curvature of a sphere. The bottom of this pole rested on a support at the centre of curvature of the dome and each brick was positioned by using the board on this pole. The walls were plastered and painted with bitumen paint.

The digester operated on cow dung sludge. The gas was piped to the kitchen. Inner tubes of bus tyres were used for storing gas. This arrangement helped to maintain a steady gas flow to the kitchen. The gas was used mainly for cooking.

Adelaide acres biogas plant

At Adelaide Acres, a centre for training cooperative personnel, a demonstration digester using night sail was constructed.

An ordinary sceptic tank was converted into a digester by casting a concrete slab on top. The manhole was modified so that a lid with a gas pipe could be fitted. The inside was plastered with waterproofing plaster and painted with bitumen paint. Water from the showers and hand basins was diverted away from the digester so as not to further dilute the slurry.

The gas from this digester was passed through another small Indian type digester and collected in the gasholder. The gas was piped to the kitchen where it was used for cooking. Gas production could not be measured but a meter was fitted to measure the gas consumption.

Coffee waste and left over maize meal were used in this digester because cow dung was not easily available.

Kushinga Phikelela Biogas Plant

Kushinga Phikelela is an Agricultural Institute situated about 100 km east of Harare. The place was chosen for demonstrating the generation of electricity using biogas.

An 80 m^3 steel digester was erected. Biogas was stored in a floating gas holder and a butyl-rubber balloon. The spent slurry was stored in 60 m^3 lagoon. The important plant electrical loads are as follows:

1 10 kw feeding pump

1 3 kw mixing pump

1 0.8 kw fan coil

1 3 kw stirring pump

2 0.7 kw hot water circulating pump

The digester was fed mainly with cow dung although occasionally mixed with left over maize porridge from the kitchen. Gas production averaged about 2.5 cubic metres per hour. The gas engine consumed 15 cubic metres of gas per hour. The gas is used mainly to generate electricity for the milking place in the morning and evening.

Table 4 gives an indication of the cost of constructing an Indian type of biogas plant using local materials and labour. Costs for a Chinese type would be similar but does not require a gasholder and hence labour costs for welding it.

CONCLUSION

The various field trials have illustrated various degrees of success. Problems encountered so far have been as follows:-

- poor construction of digesters due to lack of proper know-how
- difficulties in maintaining and managing the plants. This was particularly noticed at schools where nobody took charge of the plant. Individual households managed their plants efficiently.
- lack of proper communications between researchers and beneficiaries. This is due to lack of transport for researchers and development officers.

Biogas technology is becoming more popular in rural areas. A number of plants have been built so far (Table 5). Most of the plants can be regarded as technically successful. They provide gas for cooking and also a certain amount of lighting. The excellent crops of maize and vegetables grown in the vicinity of the plants bear testimony to the excellent quality of the fertiliser produced in the digesters.

TABLE 1: Characteristics of two biogas substrates

Component	Pigeon waste % of Feed	Pigeon waste % of TS	Coffee waste % of Feed	Coffee waste % of TS
H_2O	6.33	0.00	83.76	0.00
TS	93.67	100.00	16.24	100.00
VS	33.96	36.26	12.41	76.37
FS	59.71	63.74	3.84	23.63

TABLE 2: Biogas production over 16 weeks

Time (wks)	Coffee waste Ave. gas yield $m^3\ kg^{-1}$ VS day-1	Coffee waste VS %	Coffee waste TS%	Pigeon waste Ave. gas yield $m^3\ kg^{-1}$ VS day-1	Pigeon waste VS %	Pigeon waste TS %
1	0.14			0.42		
2	0.12	11.00	2.84	0.31	36.60	1.07
3	0.15	13.00	3.07	0.35	42.94	1.64
4	0.13	12.20	3.72	0.23	48.10	2.14
5	0.11	11.30	4.36	0.23	51.95	3.83
6	0.13	11.80	5.03	0.26	39.09	6.30
7	0.10	13.60	6.82	0.09	32.45	8.66
8	0.07	16.20	2.82	0.06	33.13	8.00
9	0.05	18.80	4.88	0.06	32.29	8.70
10	0.25	22.30	6.07	0.06	37.22	3.54
11	0.45	27.60	6.44	0.15	40.00	4.86
12	0.35	30.80	6.85	0.17	39.48	5.10
13	0.62	32.80	7.84	0.34	44.41	6.78
14	0.37	30.10	8.28	0.26	46.02	6.35
15	0.14	30.70	7.81	0.32	43.61	7.74
16	0.04		8.18	0.13	43.52	7.68

TABLE 3: Advantages of premixing biogas with air

With Premixing	Without Premixing
Complete combustion	Incomplete combustion
Air supply adjustable	Carbon monoxide formation
High efficiency heat to cooking vessel	Low thermal efficiency
Saves gas	Wasteful of gas
High temperature	Low temperature
Short clean flame	Long, wavy and sooty flame
Non conscious flame	Luminous flame

TABLE 4: The following materials are required for a 10cm³ Indian type plant which was found suitable for a family. For the Chinese type plant the gasholder and labour costs for welding are not required

		Quantity	Approximate Cost
Cement		30 bags	150.00
Bricks (common)		3000	Not normally bought
Sand (river and pit)		-	"
Stone		-	"
Reinforcing wire mesh		Approx 10m	30.00
Paint (bitumen) + thinners		15 litres each	70.00
Impermo (waterproofing compound)		48 kg	65.00
Gasholder tank		1	310.00
Pipes and valves		3 valves 15" pipes	76.00
Inlet and outlet pipes PVC 160mm OD		12m	96.00
Total (Materials)			**797.00**
Labour	Building		300.00
	Welding		200.00
TOTAL			**500.00**

TABLE 4: List of biogas plants

	Location	Type	Size (m^3)	Gas Use	Comments
1	Domboshawa Training Centre	Indian (1)	8	Cooking	Working well since 1979
2	Chishawasha	Chinese (C)	3	Cooking	Rather small
3	Chinyika School	I	8	Science laboratory refrigerator	
4	Goromonzi District offices	C	10		Probably not operational
5	Bhora Business Centre	I	8	Cooking for business	
6	St. Pauls Nutrition Village Mrewa	C	6	Cooking	
7	Rusike School Goromonzi	C	10		Finished but not yet operational
8	St. Mathias School Tsonzo	I	8	Cooking	
9	Chisangano School Wedza	I	10	Cooking	Working well
10	Kadhani Centre Mhondoro	C	8	Cooking	
11	St. Michael's School Mhondoro	I		Cooking	Has 7 drums instead of 1 gasholder
12	Nyimo Centre Sanyati	I	8		Gasholder welded on site leakage reported
13	Poshai School Shurugwi	I	8		Gasholder not welded
14	Alvord Institute Zimuto-Masvingo	I	10	Cooking	Working well
15	Mutatiri School Zimuto-Masvingo	I	10		Gasholder being welded. Not yet commissioned.

TABLE 5 continued

	Location	Type	Size (m^3)	Gas Use	Comments
16	Charumbira Mudavanhu Zimuto-Masvingo	C	10		Plastering to be done. Not yet commissioned.
17	Masasa School Chivhu	C	10	Future science laboratory and domestic science.	Recently completed. Not yet commissioned.
18+	Adelaide	I C	6	Cooking	The Chinese digester is a converted sceptic tank used by the inhabitants.
19++	Makumbe Mission	IC		Cooking	Working well
20+	Kushinga Phikelela				Industrial generation of electricity.

N.B.

++ Not constructed by this Department

\+ Constructed by this Department and some other agency, in most cases the owner.