

A combined digester and gasholder PVC plastic tube biogas unit

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This paper describes a 5.88 m³ PVC tube biogas unit which costs only Tk 890 including expenditure on gas pipe line, stove, light and labour. This unit is expected to produce 1.7 m³ of gas per day or 5½ hrs cooking from the dung of 2-3 adult cattle.

Tube biogas digesters have been operating in other countries. They are generally cheaper than the fixed and floating gasholder types and solve design problems present in the tent model. These digesters could be constructed by small-scale industry using a hot clothes iron to join the P.V.C. sheets. Further testing of plastic material is required.

A biogas unit constructed as a complete polyvinylchloride (PVC) plastic tube could overcome problems associated with flooding, anchorage and leakage with the PVC tent model. These problems and various modifications of the design were discussed in detail in the Nov-Dec. 1982 ADAB NEWS. Major faults with the tent design are shown in Fig. 1. The width and specifications of the tent model were determined by the dimensions of locally available PVC sheets because a sample method of glueing or welding (joining) the sheets together was not known.

Construction of a combined digester and gasholder PVC tube biogas unit requires joining plastic sheets. This article describes results from December 1982 to February 1983 to develop simple methods of constructing tube biogas digesters so that they could be manufactured by small scale decentralised industries.

Construction of PVC tube

Various thickness and grades of PVC

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are available from old Dhaka in rolls, generally 138 cm (54 inches) wide and 50 metres long. By joining sheets into a tube, a digester of any capacity can be constructed to match the availability of dung etc. or the gas requirements for an individual household or community. Three biogas units have been constructed. The method used is shown in figures 2a-c.

a) Joining sheet together (Fig. 2a)

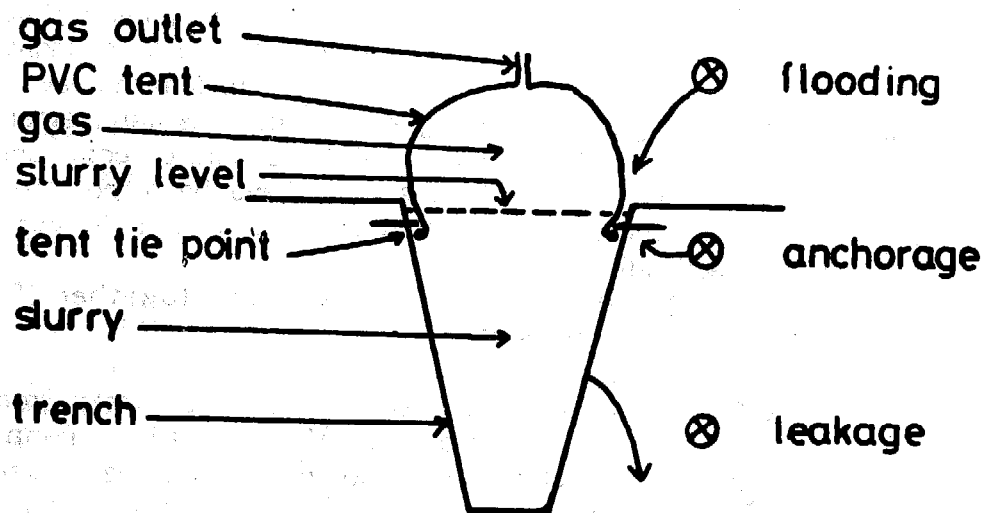
The first step is to decide what size of digester is required. Data from a 15m³ red mud PVC digester² with inputs of cow dung and water have been used to calculate Tables I a and I b and provide a guide for the length and width of the sheet.

The PVC is rolled out and the edges overlapped and joined together to form one big, flat sheet. End pieces are then cut from half a circle so that the circumference is equal to the length of the sheet (diagram 2a).

Formulas

Circumference of circle = $\pi \times$ Diameter,
for half circle

Fig 1 Tent model biogas - major problems



$$\text{Diameter (d)} = \frac{2a}{\pi} = 0.637 a.$$

where a is width of sheet.

v) **Constructing tube (Fig. 2 b)** The next step is to join the circumference of the half circle to end of the plastic sheet (a to a in Figure 2). Initially, you may think that this is impossible! Try with a piece of paper, and you will see that it is necessary to fold the sheet into a cylinder and the end half circles in to a cone before they will match. A circle (hoop) made from split bamboo will help to hold the plastic in position. The seam along the cylinder and cone is then joined with the cylinder in a collapsed or flat position.

By using this method, the unit will have an even shape with the end cones joined to the cylinders, and the inlet and outlet pipes connected to the cones. All joins will be strong because they are overlapped.

After the unit is constructed, it is advisable to test for faulty joins or small holes in the plastic. This can be done by inflating with a motor exhaust (motor cycle/vehicle) attached to a length of old bicycle tube and pipe. Alternatively, use your lungs! Check for leakage by sound smell and bubbles, using soapy water. Keep the tube inflated as a guide for digging the trench.

c) **Complete digester (Fig 2c)** Two-thirds of the volume of the tube is now placed in the trench so it fits neatly and there are no sharp roots, stones, etc. to puncture the sheet. This is equivalent to 0.687 of the circumference (approx. 2/3), leaving one-third ballooned above the trench. It is important that the trench supports the plastic tube when it is filled with dung/water so it is only acting as a water proof membrane and not giving physical support. Thinner and cheaper plastic can then be used. A few centimeters of mud on the bottom of the trench will also help to fill any irregularities in the trench.

The gas outlet is fitted at any con-

venient place on top of the tube. Threaded elbow and coupling PVC plastic fittings are available and these can be used to clamp glued washers on the inside and outside of a small hole in the tube so as to give a good gasproof outlet.

Reinforced concrete cement pipes are secured for the water/dung inlet and slurry outlet. A 6 ft. 4 in. diameter pipe can be cut at about the 2½—3½ mark and secured to the ends using nylon rope or strips of bicycle inner tube. The inlet must be higher than the outlet so that 'each charge' displaces slurry to the outlet end. Final adjustments to the slurry level can be made after the digester is filled by altering the level of the outlet pipe.

An inlet funnel can be made from mould of earth and scraps of plastic, remaining after cutting the end 'half circle'. During rain, this can be folded over the inlet pipe to prevent water entering the digester.

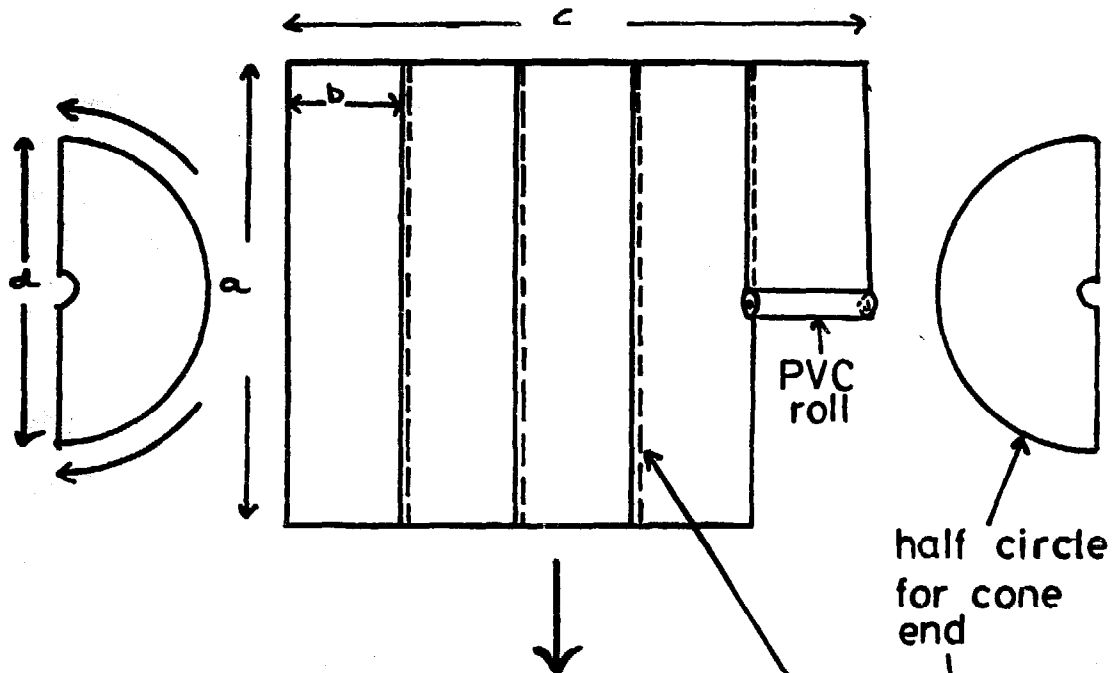
Joining PVC sheets

a) **Glueing.** The best glue we have found is 'Combined Bond' Colle de Contact, from Combined Chemicals Co., (H.K.) Ltd, with the sole export agent of Fairlite Mfg. Co., P.O. Box 79350,, Mongkok, HongKong. It partially 'melts' PVC whilst leaving a tough rubbery adhesive substance between the sheets. This is ideal for any repair work and securing the gas outlet. It costs approx. Tk 400/- for 3 kg, and 100g (Tk 13/-) would be sufficient for any minor repair work.

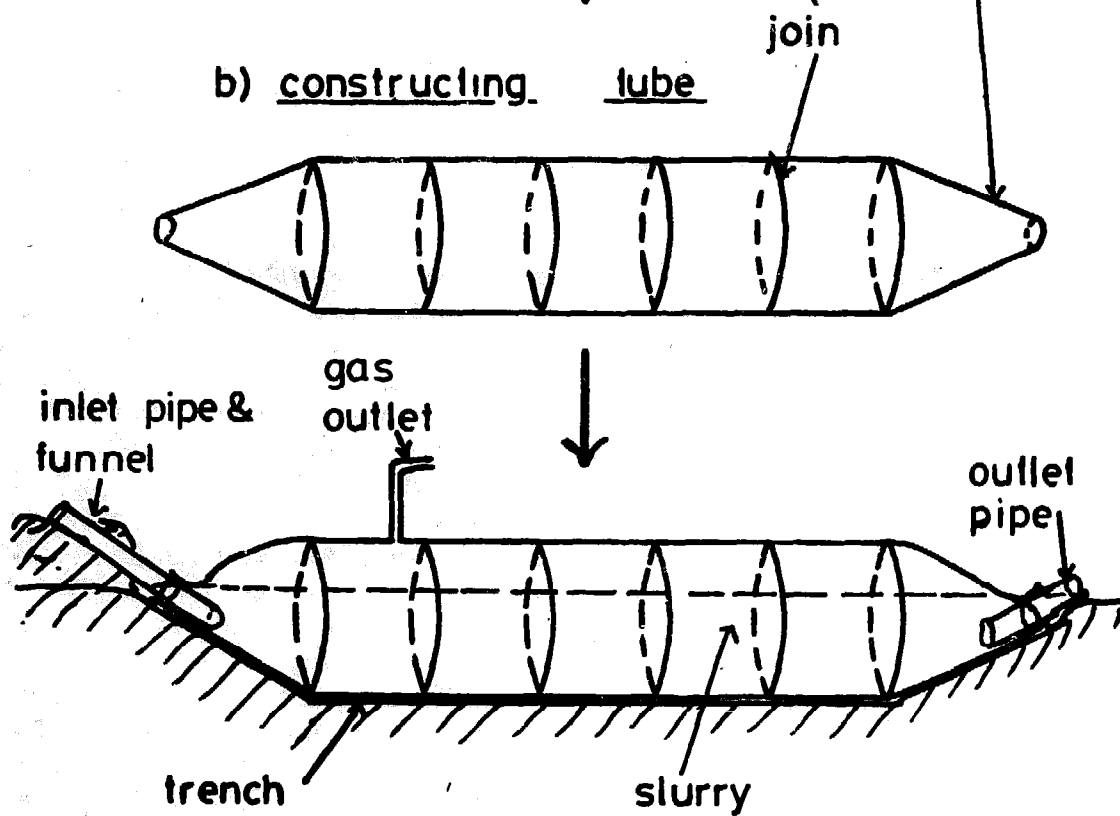
b) **Hot clothes iron.** A hot clothes iron will melt PVC and give a very strong join, provided the temperature is adjusted properly. We use a Chinese 'Red heart' (Tk 415) iron with a setting between rayon and silk with excellent results. Two layers of PVC are placed on a flat, 4-inch drive belt with newspaper on top and ironed until the paper is just singed (brown) and the plastic melted. The weave pattern of the flat belt comes through, so the plastic

Fig 2 Construction of tube biogas digester

a) welding sheets together



b) constructing tube



is not completely melted and weakened. A hot clothes iron is the preferred method at this stage.

High frequency welding. This machine (approx. Tk. 50,000) is used for making plastic hand bags, edges of folders, etc., in old Dhaka. It has given good results with heavier, reinforced plastic.

d) **Hot air welding.** A hot air welding machine (similar to a hair dryer) and used in foreign countries has not been tested yet.

Assumptions used for Table 1

- 1) **Volume of tube.** The volume in the end cone pieces has not been included in the calculations to allow for a safety factor. The width of the trench is determined by the diameter of the tube. To allow for complete digestion, each charge of dung/water should take 40 days to reach the outlet end. Although we don't know the optimum ratio of diameter to length, a long narrow tube would possibly give a better digestion because there is less chance of dung/water 'short circuiting' between the inlet and outlet pipes.
- 2) **Digester volume.** The digester (dung/water) volume occupies two-thirds of the total tube volume. This gives a gas storage space for about 18 hrs production.
- 3) **Expected gas.** This is calculated as 45% of the digester volume. In San Domingo, a mean value of 49% was obtained from biogas of a similar design, so a small safety margin is included.
- 4) **Cooking time.** Gas consumption from a single burner will obviously vary depending on the flame strength. The allowance of 300 litres/hour is 50% higher than San Domingo figures.
- 5) **Daily loading.** The key figures used are 5% Dry Matter (D.M.) in the in-

put, 20% DM in fresh cow dung and a retention time of 40 days. The input is achieved by mixing 1 dung/3 water, which is weaker than normal. By using this mixture, the unit at San Domingo has been operating for over two years now without stirring or problems with scum formation.

- 6) **Total liveweight of cattle.** Assuming a DM feed intake of 3% of liveweight, a digestibility of 50% and total collection of dung. The total liveweight could be composed of combinations of well fed cows, bulls, calves etc.

Tube biogas unit at Noakhali. Three tube biogas units have been constructed to-date. The first was made from heavy duty, nylon reinforced PVC (as used on some open-sided buses) and delivered on 12 November 1982 for installation and testing at the Bangladesh Agricultural Research Institute. Information is not available at Maijdee on installation date, performance, etc. The second was installed at the Gandhi Ashram, Joyag, on 27 Nov. 1982. A major problem occurred when the tube was placed in an existing trench which was too long. When it was filled with dung/water, the soft, fresh soil packing broke away and the plastic tube was torn. This has resulted in intermittent and annoying gas leakage because the tear occurred in a position which is difficult to repair without emptying the dung/water.

The third unit was constructed at the artificial insemination station Maijdee on 3rd Feb. 1983 and it is now operating.

Details are shown in Table 2.

- 2) **Pottery stove.**

A pottery model obtained from the Environment Pollution Control (E.P.C.) Dhaka, is cheaper and more efficient than the metal domestic Titas Gas types.

- 3) Assuming that a successful light can be developed, with components manu-

Table 1(a)

Volume (m³) of tube digesters with various length and widths of sheet in meters (see figure 2 a)

Width of Sheet	Diameter of Tube (m)	Length of Sheet (c)				
		4 m.	6 m.	8 m.	10 m.	12 m.
2 m.	0.64	1.27	1.91	2.55	3.18	3.82
3 m.	0.95	2.86	4.30	5.73	7.16	8.59
4 m.	1.27	5.09	7.64	10.19	12.73	15.29
5 m.	1.59	7.96	11.94	15.92	19.89	23.87

Table 1 (b)

Calculated inputs required and gas production obtained from digesters of various sizes. (Data from San Domingo, Ref 2)

Volume of tube (m ³)	Digester volume (m ³)	Expected gas (m ³)	Cooking time (hrs)	Daily Loading (kg)		Total Liveweight of cattle required
				Fresh dung	Water	
1	0.67	0.30	1	4	13	56
2	1.34	0.60	2	8	25	112
3	2.01	0.90	3	13	38	168
4	2.68	1.21	4	17	50	224
5	3.35	1.51	5	21	63	279
10	6.70	3.02	10	42	126	559
15	10.10	4.50	15	63	188	837
20	13.40	6.03	20	84	251	1117

Table 2**Specifications and construction costs for the tube biogas unit at Maijdee**

Specifications		
Volume of tube	5.88 m ³	(205 cft)
Digester volume	3.9 m ³	(135 cft)
Daily input	dung(fresh) 25 kg	(28 Srs)
	water 75 l	(16 gallons)
Expected gas	1.7 m ³	(61 cft)
Cooking time	5.5 hrs	5.5 hrs.
Costs		(Tk)
Plastic 24 yds x Tk 21		504
Inlet and outlet RCC pipe (6ft)		50
Welding ¹		100
Labour 3 man days		75
Pottery stove ²		60
Gas tap		6
Gas pipe line (Tk 1-50 ft) plus fittings		60
Gas light ³		40
		<hr/> 890
Notes		
1) Welding using a hot iron and flat drive belt. One man-day is assumed, but it would be quicker with experience, giving a margin for small scale industry.		

factured from pottery.

Discussion

We believe that locally produced P.V.C. tube biogas units can overcome problems with the tent biogas design and the high costs associated with floating (Indian) or fixed (Chinese) gasholder digesters constructed from bricks/cement and metal. The design is not new; such units have been developed and operating in Taiwan and other places for a number of years. The experiences presented in this article on welding PVC could allow the units to be manufactured by small scale industries.

Further work is required to test different types and grades of gas-proof sheets and refine the relationships between capital cost and the expected life of the unit. In the short term, suitable plastic sheet could be part of commodity assistance to Bangladesh, while the proposed gas-based petrochemical industry could meet requirements

in the longer term.

Although it is beyond the scope of this article, biogas could form a key component of village renewable energy, nutrient recycling and sanitation. Particular emphasis could be placed on using the effluent for fish farming or vegetable cultivation given the good returns from these enterprises. Community-based tent-model, biogas latrines are already operating at a hospital in Rangpur District. The potential for individual or village based latrines, even if the gas was only initially used for lighting, cannot be underestimated.

References

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- 2) Pound, B., Bordas, F. and Preston, T. R. 1981. "The characterisation of production and function of a 15m³ red-mud PVC biogas digester." Tropical Animal Production 6, 146-153