PREFACE

In line with the ever increasing price of energy, biomass energy sources such as biogas have entered a new phase of development. Household biogas technology has enjoyed a period of rapid development, and the technology is continuing to mature, with more varieties and models developing, and the field of use becoming ever wider. In order to assist more peasants to easily choose an appropriate digester, this book has been written as a reference to aid the comprehensive use of biogas and its digesters.

This book features a systematic and detailed explanation of the types and application environments of digesters, construction and commissioning of digesters, use and management of biogas, and the comprehensive holistic use of gas.

This book is designed for farmers and friends interested in using biogas

PREFACE

Contents

Application of
Single Household Biogas Technology

Household, or 'single family' biogas technology provides rural inhabitants with a convenient and clean form of energy, along with useful by-products such as organic fertilisers and animal feed. In addition, the technology helps rural inhabitants maintain an environmentally friendly habitat by providing proper treatment to agricultural waste and animal manure.

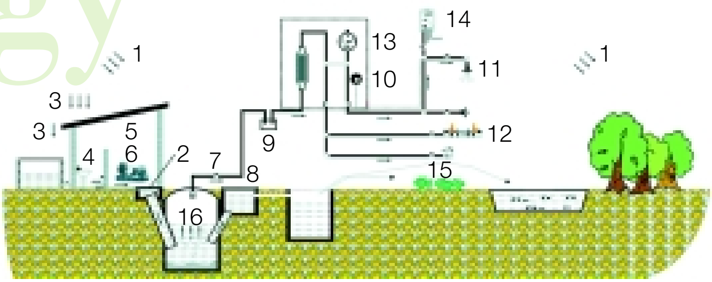
The close integration of all aspects of rural life allows bio-gas digesters to increase the value of the local economy. Since eco-friendly biogas-based rural dwellings, animal rearing, agriculture (cultivation), domestic energy use and fertilisers are very closely related, then income of peasant farmers is greatly increased as they start to use bio-gas digesters. In addition the environment of the villages is greatly improved as wood burning is reduced which in turn decreases deforestation resulting in an increased protection of the local ecology.

Single family biogas technology has been used for the past several decades with the pressurised or hydraulic biodigester being the most common. Taking this digester as a starting point, the following types of biodigesters have been developed: partially submerged plastic (polyethylene) digesters° ¢partially submerged fiberglass reinforced plastic biodigesters, and above ground plastic (polyethylene) biodigesters. These improved designs greatly increase biogas production efficiency and operational capability

Biogas is a harmless, clean-burning fuel which is the fermentation by-product of human & animal waste, domestic waste water, and agriculture waste (such as straw). Its main chemical constituents are methane (60% – 70%), carbon dioxide (25% - 40%), with the remainder includes a small amount of hydrogen, hydrogen sulphide, carbon monoxide, nitrogen and ammonia. Since biogas was first associated with swamps, it is also known as marsh gas.

Biogas is a high quality clean energy which can be used for cooking, boiling water, lighting, heating, and food storage. Liquid and solid biodigester effluent can be used as a high quality organic fertiliser which is harmless and suitable for organic farming. Liquid biodigester effluent can be used as a food supplement for pigs and aquaculture. Figure 1 shows how biogas can be used for domestic purposes. Different types of biogas technology differ mainly in the design of the digestion tank. Otherwise, the remaining parts of the biogas systems are fundamentally similar.

Figure 1: Applications of a Biodigester for Daily Life and Production Processes



1 sunlight
2 nlet
3 rain water
4 toilet
5 cow shed
6 pig sty
7 valve
8 outlet
9 regulator
10 Electronic Starter
11 gas lamp
12 gas stove
13 power meter
14 hot water system
15 crops
16 digester

Biogas is suitable for many domestic applications:

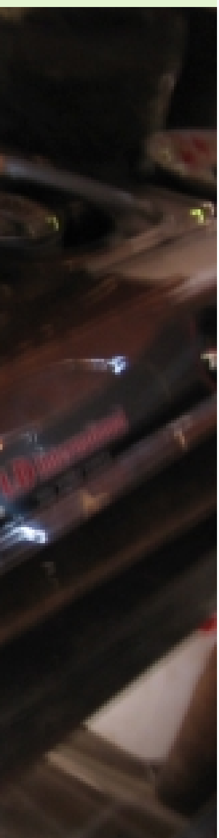
1. Biogas, a high quality fuel, improves rural life by providing both heat and light. Biogas combustion can reach temperatures as high as 1, 200° C, thereby producing a large quantity of heat. Each cubic metre of biogas has the same thermal output as 0.6 – 0.7 kg of diesel or the heating capacity of 2.3 kg of coal which can heat 65 litres of water from 20° C to boiling. Alternatively, 1 m3 of biogas can light a biogas lamp (equivalent to a 60 W light bulb) for 6 to 7 hours or keep an internal combustion engine of 1 horsepower running for 2 hours or produce 1.25 kWh of electricity.

2. The by-product of biogas can improve and stabilize yields by increasing the effectiveness of fertilizers. The liquid and solid effluent resulting from fermentation contains high proportions of nitrogen,

phosphate, potassium and other organic compound fertilisers containing trace elements.

Humic ammonium phosphate can be produced by adding appropriate amounts of mineral phosphate powder to biogas digestion residual. When these types of fertilisers are applied to fields, it can stimulate the growth of crops and promote root development, increase the brawniness of the stems, increase the size and yield of the plants, increase the size of individual grains, and accelerate the maturity of crops. It also enhances the crops' ability to resist pests and diseases. The fertilizer can not only enhance crop yields, but also improve soil quality and fertility. 1 m3 of new Biogas can produce biogas fertilizer and biogas slurry equivalent to 800 kg diammonium.

3. Environmental sanitation and health standards are increased as biogas digestion destroys harmful pathogens such as bacteria and parasites. Feces that have not gone through biogas digestion contain many parasite eggs and bacteria which are the main vectors for diseases in daily life. After digestion, the number of parasite eggs is reduced by at least 95% and the bacteria remaining in the feces will die quickly. Leptospirosis can survive up to 17 days in ordinary cesspits but only 31 hours in a biodigester. The number of hook worm eggs in the biodigester outflow pipe is 60% - 90% less than those at the inflow pipe while the corresponding reduction in round worm eggs is at least 83%.



4. The development of the livestock industry and the income of peasant farmers are increased as biogas related fertilizers improve the quality of the animal husbandry process. Livestock manure / waste can be used as raw material for biogas fermentation to produce high quality organic fertilisers. The fertilisers can then effectively increase the yield of green weeds, grass, leaves and straws from crops. When these nutrients are used as fodder for livestock, high value products such as meat, eggs and milk etc can be produced thus promoting the develop ment of animal husbandry, which will in turn increase the income of peasants farmers.

Main types of **household biogas digester**

The key technical indicator for the comparison of different types of biodigesters is the rate of biogas production per unit volume of the digestion tank: the amount of biogas that can be produced per day per cubic metre under identical climatic conditions and identical raw material. Thus the indicator is dependent on the digestion temperature and extent to which raw material is mixed. Generally speaking, either a higher digestion temperature or a higher degree of raw material mixing will increase the rate of biogas production.

Apart from the rate of biogas production, there are four factors that can influence selection of the type of biodigester technology used: cost, ease of construction, ease of daily operation and maintenance, and the area required.

Although theoretically straw from crops can be used as raw material for fermentation, due to the long fermentation period required, the difficulties in obtaining effluent outflows, and difficulties in maintenance, straw is not recommended for use in biogas fermentation.

At the present time, the types of biodigesters with good economic performance and ease of operation are:

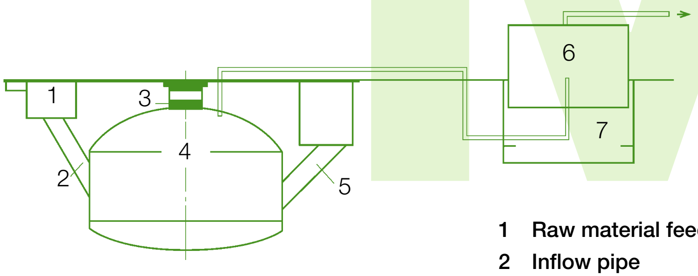
- Above Ground Plastic (polyethylene) Biodigester
- Floating drum biodigesters
- Partially submerged plastic biodigesters
- Fiberglass reinforced plastic (FRP) above ground biodigesters.

These digesters all share the same basic operational principles, and they also have gas storage facilities to stabilize the pressure of the biogas to combustion. In Figure 2, the basic operational principle of a biodigester is shown here for Floating Drum Biodigester.

The installation consists of a fermentation tank and a floating gas storage cover/drum. The biogas produced during fermentation will flow out continuously from the fermentation tank to the gas storage drum via a gas pipe connecting the two tanks. The pressure of the biogas in the gas envelop is maintained by the weight of the gas drum/cover itself and the gas is delivered via supply pipes for use by biogas stoves and other gas powered equipment.

Different types of biodigesters are suitable for different climate conditions. Table 1 provides details on their suitability.

Figure 2: Floating Drum Biodigester



1 Raw material feed chamber
2 Inflow pipe
3 Removable lid
4 Fermentation chamber / tank
5 Outflow pipe
6 Outflow Storage
7 Water tight isolation tank

Table 1: Climate and Geological Conditions and Types of Biodigesters

Type of Biodigester	Suitable climates and geological conditions
Floating drum biodigester	Low ground water table, low average rainfall, small variation in temperature with soil that can be easily moulded
Partially submerged plastic biodigester	Abundant sunlight throughout the year. Not suitable for areas with low winter temperatures
Above ground FRP biodigester	Small seasonal and daily variation in temperature. Good level of sunlight
Above ground plastic biodigester	Less sensitive to climate and geological conditions

▪ Above Ground Plastic (polyethylene) Biogas Digester

Characteristics: Made with hard plastics (polyethylene or PVC), the biodigester is placed directly on the ground. It can passively absorb heat from the sun, thereby increasing the temperature of the digestion tank. In winter, an insulation layer can be added to prevent temperature loss. The biogas production and gas storage systems can be pre-fabricated in factories, and can be installed and transported easily. A highly efficient, stable and reliable gas production system reduces problems with water or gas leakage. This type of biodigesters is economic (affordable) and has a long operational lifespan. In addition it can be adapted easily and has high degree of operationally flexibility. An electric mixing unit can be added to increase the rate of gas production.

Figure 3: PVC Above Ground Biogas Digestion Tank

Suitable areas: all climate and geological conditions

Table 2 provides details in terms of the costs of various PVC biogas fermentation tanks and their different characteristics.

Figure 3 shows a PVC fermentation tank and Figure 4 shows a gas storage bag.

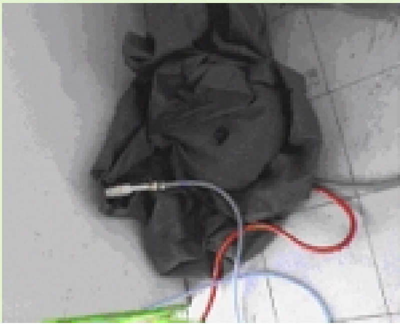


Figure 4: Gas Storage Bag

Table 2: Characteristics and Costs of PVC Above Ground Digestion Tanks

Volume of digestion tank (m^3)	Daily gas production (m^3)	Feed cycle (days)	Solid effluents produced per day (kg)	Size of family supported	Area required (m^3)	Costs (RMB)
2	1	25	20	3	1.3	1600
3	1.5	25	30	5	1.7	2000
4	2	25	40	5-8	2	3500
5	3	25	40	10	2.3	4000
6	4.5	30	50	10-12	2.6	5500
7	5	30	60	15	3	6000
8	6	35	60	15-18	3.2	6500

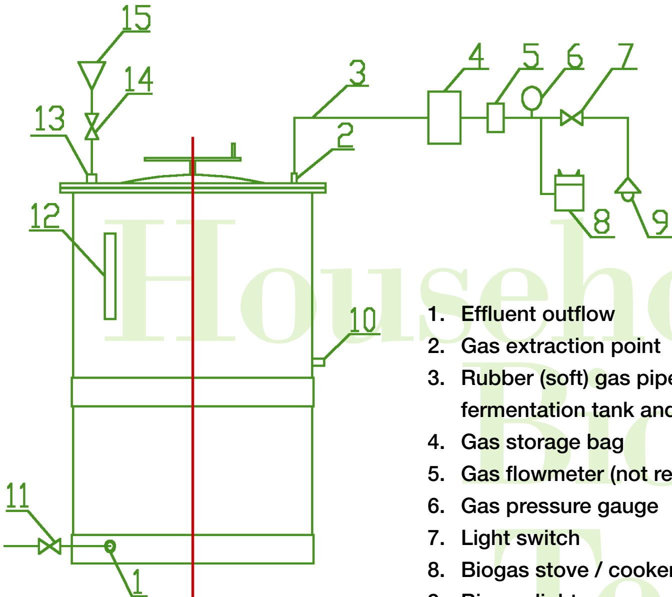
Note: Operational lifespan is assumed to be 10 – 15 years. Price varies according to regions.

Installation: Table 3 shows a list of parts. Figure 5 is the system installation diagram

Table 3: Above Ground Plastic Single Family Biogas Digester System

No.	Part name	Descriptions	Nnits	Quantity
1	Digestion tank	Cylinder	Each	1
2	Gas storage bag		Each	1
3	Two rings biogas stove	desk top	Each	1
4	Integrated purifier		Each	1
5	Gas pipe	Ø8mm	metre	10
6	Clips		Each	5
7	Tube clamps		Each	1
8	Ball valves	Ø40mm	Each	3
9	Sealing Tape		Rolls	1
10	Plastic Connectors		Each	5
11	Funnels	Ø35mm	Each	1
12	Copper 3-way connectors		Each	5
13	Plastic pipes	Ø40mm	metre	Depends on the distance between the gas tank and the stove
14	Plastic connectors	Ø40mm	Each	2

Figure 5: Above Ground Plastic Biodigester Installation Diagram



1. Effluent outflow
2. Gas extraction point
3. Rubber (soft) gas pipe connecting fermentation tank and gas tank
4. Gas storage bag
5. Gas flowmeter (not required)
6. Gas pressure gauge
7. Light switch
8. Biogas stove / cooker
9. Biogas light
10. Temperature sensor
11. Effluent outflow tap
12. Observation window
13. Feed inflow
14. Feed inflow tap
15. Feed inflow funnel

To avoid insufficient gas pressure, the digestion tank should not be sited more than 30m from the kitchen where the biogas will be used.

Safety warning:

- Use of fire or the lighting of fire is strictly forbidden near to the digestion tank or the (external) gas pipes
- Entry into the digestion tank is strictly forbidden without proper inspection and examination
- Lighting of fires is prohibited near the gas outlet and the effluent outflow at the digestion tank

■ Floating Drum Biodigester

Characteristics: Gas pressure in the digestion tank is low and it has less stringent requirement for prevention of water seepage from/into the fermentation tank. However, the cost of construction of the biodigester is high, requiring larger area and longer construction time and it is more difficult to construct. The biogas product system can be affected easily by the level of groundwater table, annual rainfall and variation in winter temperature (where the system is installed). In order to increase the temperature of the fermentation tank, these systems are installed inside greenhouses or in covered animal sheds and slurry /slag removal pumps are used for stirring and slurry removal

Suitable areas: Suitable for areas where groundwater table is low, with low average annual rainfall, with soil that can be easily worked (moulded) and small variation in winter temperature for example: Shanxi, Gansu and Ningxia provinces in China.

The characteristics and cost of floating drum biodigester fermentation is indicated in Table 4

Table 4: Characteristics and Costs of Floating Drum Biodigester

Volume of digestion tank (m^3)	Daily gas production (m3)	Feed cycle (days)	Area required (m^2)	Solid effluents produced per day (kg)	Size of family supported	Costs (RMB)
8	0.5	15	5	20	2	2,500
12	1.5	30	10	30	3	3,000
50	10	30	20	35	3-4	20,000

Note: Operation lifespan 5 – 8 years. Price varies according to regions

Installation: Table 3 shows a list of parts. Figure 5 is the system installation diagram

■ Fermentation tank design:

1. Cylindrical tank, domed roof, sloping base, roof (top) window, movable lid, tank base slopes downward from the raw material inlet down to effluent outlet, cover for each inlet / outlet / openings, floating gas storage drum and associated hydraulic tank

2. The arc/diameter ration of F 1 /D=1/5 , for which the tank water height (H) is set at H = 1.0 M
3. The volume of the gas storage drum should be based on 50% of the daily gas production.

Required construction material is listed in table 5

Table 5: Floating Drum Biodigester Construction Material Requirements and Quality

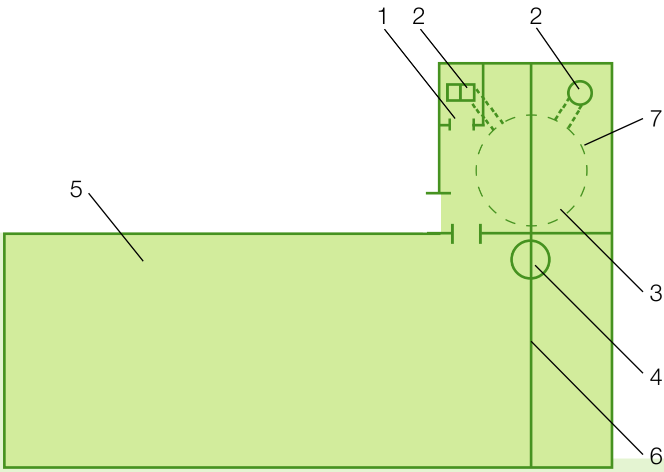
Material	8 m³	12 m³	50 m³
Cement (tonnes)	1.7	2.1	6.69
(Yellow) sand (tonnes)	4.7	6.7	20.4
Gravel (tonnes)	4	5.7	22.5
Clay bricks (block)	1114	1514	6060
Rebar	0.03	0.08	0.839
Biogas stove	two rings		
Biogas lights	No specific requirements		
Desulfuriser	No specific requirements		
Man-hours	55man-days		135 man-days

Note: No 16 rebar should be used, the unit used is tonnes.

Positioning the pit: Setting up the outline of the pit is the first hurdle in ensuring the quality of the biodigester. It is an important step in planning the positioning of the fermentation tank, the effluent outlet, the raw material inlet, the toilet, the pig sty and the glasshouse. Figure 6 shows an overall template that can be used as a reference to set up the outline of the overall system.

Pit excavation: First, it is important to define the vertical position of the baseline at which the height-zero is measured. The depth of the pit should be checked against the construction blueprint (design), which means the roof of the biodigester and the effluent outlet should be kept at the same height. Raw material inlet should be 2 cm higher than ground level. If the pit is too deep, and the fermentation tank is lower than the ground level, operation of the biodigester will be affected. If the pit is too shallow, the biodigester will rise above ground level, and may create difficulties in pig rearing or in the application of fertiliser in the greenhouse. Table 7 shows the specification for the construction of floating drum biodigesters between 8-10m3; Figure 7 gives a template for pit excavation.

Figure 6: Template for Setting the Outline of the Overall System



1. Toilet
2. Raw material inlet
3. Digestion tank
4. Effluent outlet
5. Glasshouse
6. Median line of pig sty
7. Pig sty

Figure 7: Workers Digging the Pit for the Fermentation Tank

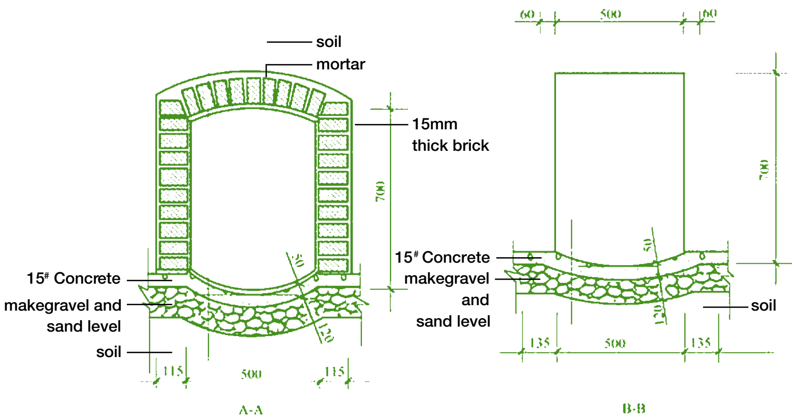
Table 6: 8-10m³ Floating Drum Biodigester Construction Specs

Volume (m^3)	internal diameter (m)	Height of pit wall (m)	Height of dome lid (m)	Radius of dome (m)	Gas drum isolation tank (Hydraulic room)	
					Depth (m)	Diameter (m)
8	2.70	1.00	0.54	1.96	2.18	1.00
10	3.00	1.00	0.60	2.18	2.28	1.10

Modular biodigester construction:

Modular biodigester construction refers to the use of cement in the construction of the pit bottom, the pit walls and the hydraulic tank bottom. Brick is used for the construction of the dome of the digestion tank and the top portion of the hydraulic tank. During the mixing of the concrete, the following specification must be strictly followed: water-cement ratio ≤ 0.65 , soil in sand ≤ 3%, mica content ≤ 0.5%, gravel diameter ≤ 3 cm, and amount of soil ≤ 2%. When using concrete it should be poured continuously, if a pause is needed between each pour, it should not exceed 1 hour. The concrete should be compacted under constant vibration while pouring to prevent air bubbles. The installation procedure is as follows:

Figure 8: Discharge Channel Constructed from Bricks (in mm)



1. **Discharge Channel:** Shown in Figure 8, the discharge channel is fabricated from clay bricks and sand-lime mortar in layers, with a cement-to-sand mixture ratio set at 1: 2.5. In order to ease construc tion the discharge channels should be 50cm wide and 70cm high, with a raised arch at the top. The top of the opening should not be less than 35cm from the top dome of the digester, in order to prevent gas from escaping under the surface of the liquid (inside).

2. **The Base and Walls:** The base and walls are both subject to pressure from pouring. The digester walls and base can be constructed using a concrete mould made of steel sheeting, wood, or bricks. This constitutes the internal layer of the mould, with the dirt wall of the pit as the outer section. Due to its high costs steel sheet moulds are rarely used, therefore wood and brick moulds are preferred. Where several digesters are to be constructed in the village, it is more common to use wooden moulds. Where only one is to be built, a brick lining should be adequate.

   The usual course for constructing a brick mould is as follows: first, soak the bricks in water to prevent problems with removing the mould. Then, lay the bricks horizontally in a line around the edge of the mould, with each layer added on type slightly offset, taking care to keep the bricks free of mud and dust. Once each layer of bricks has been completely laid, pour a layer of concrete (between the bricks and pit wall), and once correctly braced and compacted, continue laying the next brick layer. The concrete should be made up on the following ratio according to weight: cement:sand:gravel 1:3:3. Walls should be poured to a height of 1m and a thickness of 5cm.

3. **Digester Dome Shaped Cover.** Up until now, the covers of separated floating cover type digesters have been constructed from bricks and a vertically positioned intake pipe. The intake pipe should be posi tioned properly before construction of the brick dome commences, the usual ceramic pipe dimensions are 200mm diameter x approx 600mm long. This pipe is secured to a wooden peg, such that it stands vertically positioned (top-to-bottom), and is fastened to the digester wall. A suitable depth for the pipe to extend into the digester is 250 - 300mm from the dome.

   The brick dome cover can use metal fittings or rope to hold the bricks in place. Bricks should be built out from the position of the intake pipe, although cement will be needed close to the pipe itself. Bricks used in construction of the dome cover should be good quality. They should first be pre-soaked in water; care should be taken to ensure the exterior is wet whilst the inside remains dry. They should be laid using a 1:2 cement: sand mortar ratio. Care should be taken to ensure all gaps are filled, and the bricks are flush against each other, using smaller rock fragments or gravel as wedges to complete each layer. Attention should be paid simultaneously to the laying of bricks and the need to maintain shape of the dome.

   When 3 to 5 layers have been achieved a 1:3 cement: sand grout should be applied carefully. When applying grout to the 1st ring of bricks, the thickness should be between 30-50mm, to substitute for arch supports. As the laying and grouting is occurring, some of the dirt can also be returned, and spread evenly. Before replacing the soil, a few layers of brick should be added to the intake pipe, in order to prevent soil from entering the digester while it is being replaced. 240mm is an appropriate diameter for the intake pipe, while the length should be sized according to need. At first, the replaced dirt should only cover 60% of the dome surface, in order to prevent collapse. After about 10 days soil can be replaced so that it totally covers the recessed dome. A construction blueprint for a digester dome cover is given in Figure 9.

At the same time as the dome is constructed, the top half of the water pressure chamber should be constructed by way of laying quarter-piece bricks vertically (standing up), using 1:3 ratio cement (one part cement to 3 parts sand/lime).

When it comes time to close up the top of the dome, a 9-19mm copper gas extraction (outlet) pipe should be installed as suggested per Figure 10.

Figure 9: Dome Cover under Construction

Figure 10: Gas Extraction Pipe

4. **Digester Base:** First, a layer of gravel should be put down and covered with a 1:4 cement: sand slurry. This should then be followed with a layer of concrete made from cement, sand, and gravel in a 1:3:3 ratio. This concrete layer should be at least 8 – 12 cm thick. An example is given in Figure 11.

5. **Sealing the interior of the digester tank.** Walls constructed from concrete and bricks only provide the digester with structural support, and do not prevent gas leakage. Therefore, it is necessary to treat the wall of the digester with a sealant to prevent gas and water leakage. There are two main treatment types: the 7 layer method, and the 3 layer method. The 7-layer method should be used for the gas storage chamber and the area of the digester interior near to the feedstock intake pipe. The 3-layer method should be used for the base, walls, water pressure chamber, and discharge channel.

7-Layer Method

Layer 1: #45 cement and sand-lime are used to from a mortar with the ratio of 0.3:1

Layer 2: a mixture with a 1:2.5 ratio of cement to sand is applied to a thickness of 0.8 to 1 cm

Layer 3: a 0.1 cm layer of soda ash is applied

Layer 4: a mortar of cement and sand in the ratio of 1:2 with a thick ness of 0.4 cm

Layer 5: 0.1cm of soda ash

Layer 6: 1:1 mixture of fine sand & ash to a thickness of 0.3-.04cm

Layer 7: 3 applications of soda ash slurry.

3-Layer Method

In the case of the 3 layer process, the processes described above for the 2nd, 6th and 7th layers should be applied.

6. **Curing.** All components of the digester made from concrete or cement will need to undergo curing, and for this to naturally occur the ambient temperature should be above 5 degrees Celsius. Surfaces exposed to the elements should be covered with straw matting and the matting should be slightly moistened. The matting should be kept up for a period of 7 to 10 days. In spring and in autumn it is

also important guard against frost. In order to achieve the aim of success fully curing the concrete and brickwork, once the inside has been treated with sealant, then the intake, discharge outlet and top of the digester should be covered or wrapped with film. Once the required period has elapsed, the digester should be examined and (if possible) pressure tested. Upon passing inspection, feedstock can be put into the digester and it can begin to be used. If it rains within the first twenty-four hours of operation, then the digest should be immedi ately filled with water to approximately half capacity, in order to prevent water seeping under the base and floating the digester out of its hole & footings.

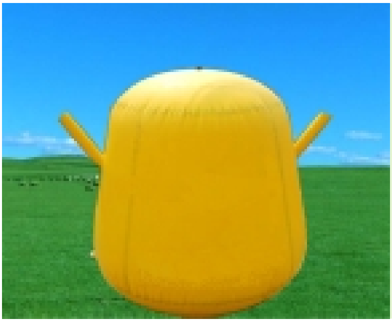
Figure 11 Constructing the Base

▪ Partially Submerged Plastic Digester

Characteristics: The characteristics are generally the same as the Above Ground Plastic Digester. To enhance stability, a shallow hole is required, and to prevent leaks from being created sharp tools should not be used for making the hole. Figure 12 below shows the fully constructed digester, with the extensions on the left and right side forming the outlet and inlet, with gas being extracted from the top of the dome.

Suitable Locations: Areas with abundant sunlight all year round are best. It is not appropriate for regions with low winter temperatures. A comparison of installation specifications and cost for different scenarios is given in Table 7 below.

Figure 12: Partially Submerged Plastic Digester (basic form)



Hous Biogas Techn

Table 7: Comparison of Different Digester Sizes

Digester Capacity (m3)	Daily Gas Production (m3)	Cycle Period (Days)	Quantity of Sediment Produced Daily (kg)	Persons in User Household	Area Occupied (sq m)	Price (RMB)
2	1	15	20	3	1.7 × 1.2	1210
3	1.5	15	30	3-5	1.7 × 1.8	1235
4	2	20	35	3-5	2.2 × 1.6	1270
5	2	20	40	5	1.8 × 2.4	1445
6	2.5	25	45	5-8	1.8 × 3.5	1550
7	3	25	50	8	1.8 × 4	1665

Digester Installation:

1. The position selected for installation is usually one with abundant sunshine. In northern areas (in northern hemisphere countries), the digester should be constructed in a greenhouse.

2. For the inlet and outlet pipes hard plastic (e.g. PVC) or metal piping should be attached to the concrete. Where the piping is in contact with the concrete, use putty or waterproofing tape to create a seal. The inlet and outlet should be attached to the digester only after the digester has been stabilized, to prevent the pipes from pulling out of the cement.

3. Once the digester has been completed, the inlets/outlets should be covered with film or a concrete plug. However film creates a better seal.

4. The gas extraction nib should be attached at the correct depth, with the threaded section in contact with the digester shell, using putty or sealing tape to seal around the joint. The other end should be attached to the extraction pipe.

5. The extraction pipe should be at a slight angle to prevent water from building up inside the pipe, allowing condensation to flow back into the digester.

6. Lights, stoves, range hoods, valves and pipes should be kept far apart from open flames and flammables, in order to prevent explosions.

7. The inlet should be fitted with a (coarse) sieve to prevent unwanted material entering the digester.

8. If using high pressure lamps or stovetops, bricks should be placed on top of the removable cap (see diagram below), ensuring that the bricks are kept from touching the wall of the digester. The quantity of brick depends on the distance of the lamps from the digester. It is preferable to use low pressure lamps.

9. Installation should be as per the diagram given in Figure 13.

   Points to consider:

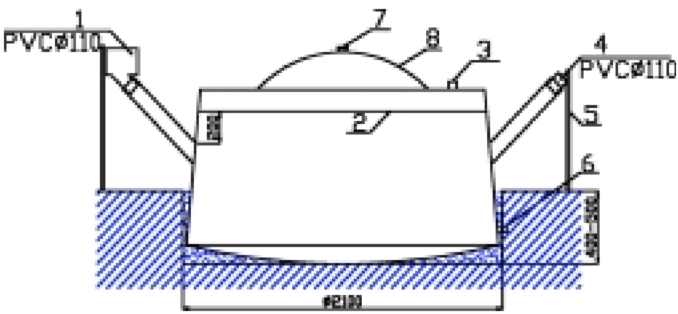
1) Installation is convenient, only requiring a shallow hole of 400 to 500mm deep.
2) For households or users with sufficient finances, the digester can be

placed in a greenhouse. Otherwise covering the outside of the digester with rice straw or netting will extend the life of the digester.

3) Wooden stakes can be used to support the intake pipe/inlet.

4) Upon successful installation of the new digester, once it has started to produce gas add water to the water bag.

Figure 13: Installation diagram.



1. Inlet
2. 'Fill to' line
3. Gas Extraction Point
4. Discharge Outlet
5. Wooden stakes
6. DN40 Stopper/Plug
7. Water Bag
8. Flexible Cap (membrane).

▪ Fiberglass Reinforced Plastic (FRP) Partially Submerged Digester

Characteristics: The overall characteristics are similar to the Plastic Above Ground Biogas Digester. For stability, a shallow hole should be dug, and the digester installed within. In order to take advantage of the solar energy to heat the slurry the top of the Biogas digester is made of a panel of evacuated glass. When gas is produced, the slurry is forced by the pressure of the biogas to move into the hydraulic (water pressure) chamber, where it is heated by the sun. The digester is made from imported resin, which is light and durable, easy to assemble/disassemble, seals well, prevents spoilage, and is reasonably priced. The digester produces gas all year round, with liquid escaping through a valve, and sediment extracted using a hand pump as required. There are several safety features included in the design such as adjustable pressure, back-fire protection, and sediment separation. As per Figure 14, the digester items at the top of the digester are the inlet, gas extraction pipe and gas release valve/opening.

Suitable Locations: The best locations are where there are not strong seasonal nor strong diurnal temperature differences, and where there is sufficient sunlight.

A comparison of installation specifications and cost for different scenarios is given in Table 8 below.

Table 8: Comparison of Different FRP Digester Sizes

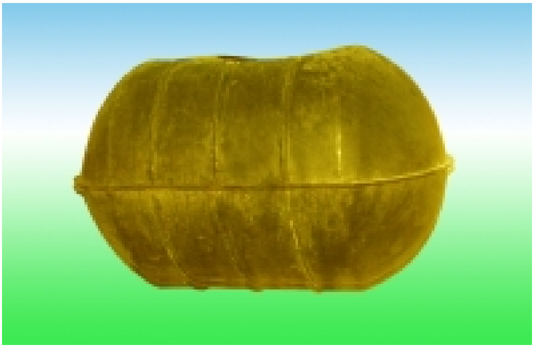
Digester Capacity (cubic m)	Daily Gas Production (cubic m)	Cycle Period (Days)	Quantity of Sediment Produced Daily (kg)	Persons in User Household	Area Occupied (sq m)	Price (RMB)
2	2	20	20	5-8	∮1.3 × 1.5	2280
3	3	20	30	5	∮1.5 × 1.7	2480
4	4	20	40	5-8	∮1.5 × 2.3	2880

Note: Average Useful Life is 3 years, prices differ between regions.

Safety warning:

- Using open flames or playing with fire near to the digester or extraction pipes is strictly forbidden
- Digesters that have not passed inspection should not be used

Figure 14: Household FRP Partially Submerged Digester



Installation: As per Figure 15 below.

1. **Site Selection:** It is preferable that the digester is within thirty meters of the kitchen or point of use, to ensure that gas pressure is sufficient. The family pigsty, kitchen and digester should be positioned as close as possible to increase the efficiency of mucking out the sty and shifting manure into the digester.

2. **Digging the Hole:** To easy positioning the digester in the ground the diameter of the whole should be constructed slightly larger than the diameter of the digester. The lower section of the hole should be dug to match the shape of the digester, digging out small sections for the intake pipe and hydraulic/pressure chamber.

3. **Installation:** Prior to installing the digester, the shell should be carefully dusted and inspected for faults, and repaired if found. The two half-sections of FRP should be thoroughly cleaned out, and rough sections should be sanded down with sand paper. Then the two halves of the digester should be placed together such that the dome sections face opposite directions and the flange or tabs at the base of each section are flush. The epoxy or bonding solution provided should be thoroughly mixed together, and then spread evenly over the gap or groove formed between the two adjoined sections of the digester, then fasten the M10 sized bolts or screws. Again, a second batch of epoxy or sealant should be mixed together and spread evenly over the gap or groove formed between the two adjoined sections of the digester. Prior to attaching the intake and pressure chamber to the

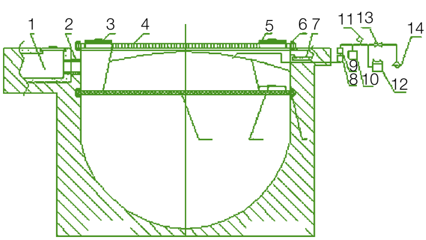
main digester body, a quick test should be done to ensure that screw holes align and the remaining epoxy/sealant should be spread evenly over the parts to be joined. Before placing the digester in the hole, first spread a 30-50mm layer of fine grouting sand, with a thicker layer at the base of the digester arc. Once the digester has been lowered into the whole, using wooden tomato stakes or something similar, slightly raise the digester again and gently slide in excess soil around the digester. Finally, use adhesive to attach the flexible cap to the digester, screw down with buckle resistant bolts, and then add water.

4. **Backfilling:** Once the digester is installed as above, fine aggregate or sand should be used to backfill any gaps between the edge of the hole and the digester. Alternate between adding soil and adding a small amount of water (to aid in compacting the soil), then use a wooden pole or similar rod with a flat base to tamp down the soil around the digester. In areas with a high water table, water should be added to fill approximately half of the digester. When tamping down the soil around the digester, care should be taken not to damage or pierce the digester itself.

Safety warning:

- **Using open flames or playing with fire near to the digester or extraction pipes is strictly forbidden**
- **Digesters that have not passed inspection should not be used**
- **It is strictly forbidden to light the extraction pipe or discharge pipe.**

Figure 15: FRP Digester Installation Diagram



1 Deep Sand Pit
2 Connecting Pipe
3 Inlet/Intake
4 Evacuated Panel
5 Outlet for discharging liquid (flexible cap)
6 Screws/Bolts
7 Overflow Outlet
8 Safety Release Valve
9 Desulphuriser (Scrubber)
10 Gauge
11 Pressure Gauge
12 Stove (not to scale)
13 Light Switch/Valve
14 Biogas Lamp
15 Sealed Container
16 Main Moveable/ Flexible Cap

Use & Management of Household Digesters

Basic Operation Steps for Household Digesters

Investigating Leaks: A detailed description is given in Section A: Methods for Finding the Location of Leaks.

Preparation of Raw Materials:

Starting Culture or Fermenting Agent: The culture used is generally a slurry obtained from an existing digester mixed with human or animal manure in a roughly a 2:3 ratio. It should be left to anaerobically digest for approximately one week covered by a plastic film. If slurry from a previous digester is not available, sludge from sewer traps can be mixed with manure and left out for a week in a similar manner. In the event this substitute can not be found, manure can be mixed with water and left out to begin anaerobically digestion over a longer period of ten days.

Pre-treatment: Once the culture has been prepared, mix the manure, culture and water together in a ratio of 1:4:19.

Beginning the fermentation process: New or thoroughly cleaned out digesters need to undergo a short period of preparatory maintenance to determine that there is no vapour or water seepage. Once this has been determined virgin slurry can be added to the digester.

1. *Preparation:* Pre-treatment of the culture (inoculant or starting agent) should be done according to requirements. The culture should form approximately 10 - 30% of the starter mixture and the density of the slurry would be approximately 6 - 11%.

2. *Inserting Virgin Slurry:* Combine the starter and culture together and place into the digester. The density of such as slurry should not be excessively high, and generally speaking the slurry density has been kept at around 4%-6%. If manure is the main ingredient, then density levels should be lower.

3. *Mixing:* The mixture should be thoroughly stirred once placed in the digester.

4. *Adding Water & Sealing the Digester:* The slurry mixture in the digester should be 85% of the total capacity. The remaining 15% is to store the gas produced.

5. *Testing of Gas Produced:* Once the reading on the gas pressure column has reached 40cm, gas should be released and test ignited. Once this has been successfully completed one or two times it can be used as a fuel. It is very important that test ignitions should be completed on a suitable burner or stove, and not at the gas extraction point or directly on the gas extraction pipe to prevent backfire in the pipe and subsequent explosion of the digester.

6. *Finalisation of Commissioning:* Once production of gas from the digester is stable, and the gas has been used [successfully], the biodigester should be in equilibrium. This means that the quantity of the micro-organisms, acid levels and methane producing bacteria are in equilibrium, and the pH level are in order (the pH should be above 6 – if not plant derived cinder ash, ammonia or clear limewater can be carefully added until the pH level reaches 7). Upon reaching end of this commissioning stage, the digester can enter normal service.

Adding Material: The basic guiding principle is that the amount removed is the amount replaced. The waste (spent) slurry or solids should be first removed before adding new material, and as material is removed care should be taken to ensure that the material in the digester does not drop below the top edge or the outlet/inlet, because gas will escape in such a case. Once material has been removed, new material should be added as quickly as possible. If there is insufficient slurry or manure to reach to original water level inside the digester, add water until this level is reached, to ensure that the gas produced will have sufficient pressure.

Mixing: Once starter culture and manure inputs have been placed in the digester it is important to thoroughly mix them to ensure that there is good contact thus speeding up the production of gas. For separation float type digesters a sediment extraction device should be used. Other digesters should use included mixing equipment.

Major Clean out: In order to satisfy both the metabolic needs of the bacteria and the needs of nearby fields (for fertilizer), major clean outs are usually performed in the spring or autumn. Twenty to thirty days beforehand, normal addition of material should cease, in order to prevent waste of the active culture. Once the major cleanout has been completed, new material should be added immediately to ensure the digester can quickly return to production and therefore use. The digester should be thoroughly cleaned including the removal of all sullage and liquid. 10-30% of the live liquid should be set aside to use as the starter culture in the next batch, in order that the digester can quickly return to service, and begin gas production.

▪ Management of Household Digesters

Maintaining Temperature During Winter: It is important to manage the temperature for naturally heated digesters in the winter when the temperature is relatively low, many different materials should be used as feedstock for household digesters. Temperature is a key factor influencing the speed of gas production, and within a certain range, the higher the temperature, the higher the speed of gas production. As such, it is important to take measures to increase temperature in the digester. If the aim is to increase winter gas production, a simple saying goes: 'eat your fill, (and) rug up well.' As winter approaches, the following steps should be completed:

1. Increase the density of the slurry in the digester, increasing to about 10%
2. Due to the large diurnal temperature difference at the start of winter, special attention must be paid to night time digester temperatures. As soon as possible, the digester should be covered; as the temperature falls, and once the sun has set, the digester should be covered with straw matting or other insulating material to keep the heat in.
3. To help raise gas production it is important to add new slurry/ feedstock and remove spent slurry diligently to provide the bacteria with necessary nutrients.
4. Diligently Circulate or Mix Digester Contents: Floatation type digesters should be mixed every three to four days. This can be achieved by cycling ten to fifteen buckets (in volume) through the pressure chamber to the entry pipe; such mixing can be achieved in other digesters using the equipment supplied.

Daily Management: To prevent damage to the digester the pressure gauge should be checked often, and when vigorous gas production causes overpressure, gas should be used as quickly as possible, or a suitable stove ignited. If using a directly coupled pressure gauge attached to the extraction pipe, a safety valve should also be employed to prevent digester explosion. In the event of an explosion, nearby open flames must be extinguished, to prevent further fire-related accidents.

In regards to separated float digesters, if feedstock has recently been added to the digester, take care not to rashly remove spent slurry or enter the digester without first taking adequate safety precautions. The safety precautions include: first, open the cap and flush the inlet/outlet and top with fresh air (or use a ventilation fan to refresh the airspace). Second, observe the digester for 15 – 20 minutes, and when it is cleared out, the digester can be entered; if abnormalities exist, entry should be strictly avoided. Third, persons entering the digester should be secured by a safety harness and observed by suitably qualified personnel. If the worker inside the digester signals discomfort, the observer should pull them out immediately, after which the affected worker should be taken to a ventilated area to recover. Once the floating cap or cover has been exposed, smoking is then prohibited, and there should be no open flames within the vicinity of the digester. Workers inside the digester should use electric torches or mirrors to light the digester; open flames are strictly prohibited. Open flames should never be used to burn off surplus gas directly in the digester, as that would cause the digester to explode.

Suggestions to Improve Gas Production: Ensure the temperature is kept relatively high; when conducting the biannual large scale cleanout, retain some fermented liquid to use as the starter culture for new batches; stir the mixture often.

Methods for Finding Leaks in the Digester: Generally speaking, first check the exterior, secondly check the interior, gradually checking off likely places, and treat according to the problem, on the basis of the following steps:

1. Checking the External Surfaces for Leaks

Coil up accessible flexible pipes and tie with a string. Submerse this roll in water and pass air or gas through it (or blow into it). At the same time, check the pipe, valves and stoppers for air bubbles because these indicate holes or leaks. When the hosing and joints are in use, a brush can be used to apply soapy water to valves, elbow joints, connectors, T-joins, step-down/step-up fittings and the pipe, checking for bubble formation. In addition, it is important to check around the gas extraction point, the joint between digester cap and the top of the digester, and around the floating cap. These are areas where leaks easily develop and should be inspected regularly.

2. Process for Inspecting Internal Surfaces

In the case of separation float digesters, first check for any external leaks as described above, when it has been confirmed that the leak is internal the contents of the digester must be removed and the digester cleaned out. After allowing time for all of the gas to dissipate, the digester walls, cap, base and outlets/inlets should be visually inspected for holes and cracks. The gas extraction pipe should be fixed in place where it cannot move. It is especially easy for cracks to form around the inlet/outlets; therefore they should be carefully examined. The walls of the digester should be checked for signs of seeping water; in digesters where this is not an obvious layer of dry cement, ash can be applied, whereby damp spots and lines can be readily identified as likely leaks. Leaks in other digester types are generally found by external examination. This can be achieved on operation digesters by spreading soapy water over the surface of the digester and introducing air to the chamber, checking for bubbles that indicate leaks.

Safety Points:

- STRICTLY No fires permitted near the digester or extraction pipes.
- STRICTLY No unqualified personnel to are to enter digesters.
- STRICTLY No fires should be lit at the spent slurry discharge outlet nor directly on the gas extraction pipe.

Safe Fermentation:

1. In order to maintain the helpful gas producing bacteria, care should be taken to insure that they are not poisoned by pesticides such as: organic bactericides and antibiotics, including recently sprayed crop waste or leaves, and disinfected animal waste, and naturally occurring pesticides such as garlic and peach leaves etc, as well as heavy metal compounds & salts (such as wastewater from electroplating processes). These compounds should NEVER be allowed to enter the

digester. If they do enter the digester, gas production will stop. In the event that this occurs, the entire contents of the digester must be removed and refreshed with completely new materials.

2. It is forbidden to empty oil, bone meal or phosphorous material into the digester, or any products containing phosphorous.

3. Poisoning due to alkalinity must be avoided. The main cause of this is the over addition of material with high alkalinity, for example lime. Where the pH exceeds 8.5, this generally results in poisoning of the bacteria and is sometimes accompanied by an increase in ammonium nitrate. The effects of alkaline induced poisoning are similar to acid induced.

4. Preventing Ammonia Related Poisoning. The main causes are the addition of personal or animal waste with a high nitrogen content, excessive density of the slurry mix or the lack of bacteria/starter culture. It has similar effects to the alkaline situation decided above.

Safety Management:

1. Caps should be placed on the discharge pipe (or channel) to prevent people and/or animals from entering the digester and accidentally dying.

2. Regularly inspect the gas transmission system, to prevent fires arising from leaks.

3. Children should be educated to understand that they should not play with fire near the gas extraction pipes, distribution system, nor digester, and [the children should be taught] not to play with valves and switches.

4. Pressure on the pressure gauge should be regularly checked and changes observed. When gas production is vigorous, and pressure exceeds desired levels, excess gas should be quickly used up or burned off on a suitable stove, in order to prevent swelling of the digester and subsequent explosion. Water in the pressure gauge should be refilled. In the event that the top or cap is blown off the digester, nearby open flames should be immediately extinguished, to prevent further explosions.

5. When adding materials and slurry to the digester, if there is a lot of material, new material should be added slowly. If removing a

substantial amount of spent material, and the pressure gauge subsequently drops to zero, open the material inlet, in order to prevent damage that would result from excessively low pressures.

6. Adequate steps must be taken to prevent wintertime and frost damage.

Safe Use of Gas:

1. The first step towards the safe use of gas is selecting components that have passed national certification standards.

2. Gas lamps, stoves, and transmission pipes should be kept apart from firewood and other flammables, in order to prevent fire. In the event of a fire, it is important not to panic, but rather to immediately turn off all valves and to disconnect the distribution pipes from the extraction point on the digester. Once the fuel source has been disconnected, immediate action should be taken to put out the fire.

3. When determining if a new digester has produced gas, this should only be done by test ignition on a suitable stove or burner, and STRICTLY never at the gas extraction point or on the discharge outlet or other spent material removal point. Following this course of action will prevent explosion of the digester.

4. When using gas, first light the match or start the ignition source, in order to prevent excess gas being released and the subsequent burning of nearby personnel once ignited.

5. If putrid gas is detected in the room or rooms, nearby windows should be immediately opened and the location ventilated, making sure not to use open flames, in order to prevent possible explosions.

Safe Removal of Spent Materials and Other Maintenance in Separated Float Digesters:

1. When entering the digester to remove materials or to conduct maintenance, safety and preventative measures must be taken. The floating/flexible cap should be open for several hours, scum should be removed and a portion of the liquid removed. Open the discharge outlet, inlet and cap, to allow airflow through all three, in order to evacuate remaining gas. If persons entering the digester begin feeling dizzy or stuffy, then they should be immediately removed from the digester and allowed to rest. When entering digesters that have been

out of use for several years, special care should be taken as gas may be trapped under a crust of dung and sediment on the floor. If persons carelessly enter digesters without regard for safety precautions and without taking suitable safety measures, accidents are very likely. As much as is possible, mechanisms provided to remove material from the digester should be used, thus negating the need for people to enter the digester, increasing safety and convenience.

2. When opening the digester cover, it is important that no nearby persons are smoking, and that no other sources of ignition are present. When inside the digester, only battery flashlights or electric lights should be used for illumination; lanterns and candles should not be used, and workers may not smoke in the digester.

Remedies for Common Problems or Accidents:

1. **Fainting:** In the event of workers fainting (passing out) inside the digester, and the person cannot be quickly retrieved, then methods must be used to fan fresh air into the digester to ventilate it. Under no circumstances should other people jump into the digester blindly without taking this precaution, otherwise further persons may faint or asphyxiate.

2. **Treating Faint Victims:** Once retrieved, the person who fainted and/or suffocated persons should be taken to an area sheltered from wind. Their clothing and belt should be loosened whilst keeping them warm. Lightly affected persons will quickly regain consciousness, whilst severe cases should be taken immediately to the nearest hospital.

3. **Extinguishing Fires:** For persons burned by methane burning clothes should be removed immediately. The person should lie on the ground and roll about, or jump into water. Surrounding individuals can assist the victim to use other suitable methods to extinguish the fire. Bare hands should not be used to swat at the fire, and victims should not run about in a flurry or panic, as this will increase the intensity of the fire.

4. **Treatment of Burns:** After extinguishing all fires, cut away burnt clothing, and use clean water to gently wash the affected area. Use q fresh clothing, sheets or bandages to wrap burns and/or complete body as appropriate, ensuring in cold or cooler seasons that the person

is kept warm. Then the person should be taken to the nearest hospital's emergency treatment department.

Below is a chart detailing common problems and suggested courses of action.

Table9: Chart Showing Troubleshooting Approaches & Remedies

Problem Symptom	Cause	Solution
Gas quality is good, but production rate is low	Ratio of inputs is not correct; Too much spent slurry	Choose a ratio or thickness of between 6 and 10%; Regularly remove spent materials and introduce new feedstock/manure.
New slurry quantity is accurate, mixture ratio is correct, but no gas is produced	Leakage	Search for the leak as described in the above section and repair as appropriate
Gas production is sufficient, but is not flammable	Acidity/Alkalinity incorrect, most likely too acidic; too much new material has been added	Add a small amount of lime or ammonia to the mix; Add old manure from the base of a previous storage area
Gas production is good, water level (on gas meter) rises sufficiently but then stops	A hole in the input pipe	Examine and repair input pipe
As gas is burning, pressure gauge responds erratically, and flame flickers	Water is lodged in the transmission pipe	Check joins in the pipe for water, disconnect, and remove.
Pressure on the gauge appears high, but falls immediately following ignition	Too much material inside the digester (in the case of float digesters) Transmission pipes are blocked	Remove some of the contents; Flush out the distribution pipes.

▪ Installation and Use of Gas Lights & Stoves

To safely, efficiently and correctly use gas lamps and burners, first it is necessary to select components that meet or exceed national standards for burners and lights.

There are many different kinds of stove tops (burners) and lights, and as such there are differences in installation. The best guide is to follow the manufacture's installation instructions.

Comprehensive Use of **Household Biogas**

Making full use of the products and by-products of gas production is easy, has low capital cost, and is economically efficient. In addition to its usefulness as a fuel, methane can also be used in the preservation and storage of fruit and vegetables, and to protect cereals & seeds from insects. The spent slurry can be used to feed fish and pigs or as a fertiliser, or to soak seeds. Some applications are detailed below:

▪ Preservation of Fruit:

This example uses storage of oranges to demonstrate the basic idea. Storage of oranges usually involves an enclosed space or room, into which gas is injected. Every day for ten days, 0.06 m^3 of methane (biogas) per cubic metre of area to be treated is introduced to the room, increasing gradually to 0.14 m^3 after the initial ten days has elapsed. In the case of boxed or cling-wrapped oranges, gas is added every three days. In the initial period, say the first fifteen days, for every cubic metre to be treated, add 0.1 m^3 methane; in the intermediate period (after fifteen days) add 0.085 m^3/m^3, and in the final period before use/shipment (and the storage temperature is 12-15 degrees C) then add 0.0425 m^3/m^3 methane. After storage for a period of time, every ten days the gas should be changed and the fruit turned over; after this initial period fruit can be turned over and the gas changed every half month or so. At this time the fruit should be examined in order to rectify problems such as bruising, disease, rot, early maturity, premature ripening, or dryness. In this way economic loss can be prevented and the yield improved. When moving boxes and individual fruit pieces, care must be taken to gently remove and place the fruit, to avoid damaging the fruit. To ensure the hygiene of the storage environment, the floor and walls should be treated at set intervals with 2% mixture of water and limewater.

▪ Preventing Pests in Barns & Granaries:

Methane in the form of biogas can be used to eradicate pests from grain storage for up to one year. The following includes instructions on how to achieve this.

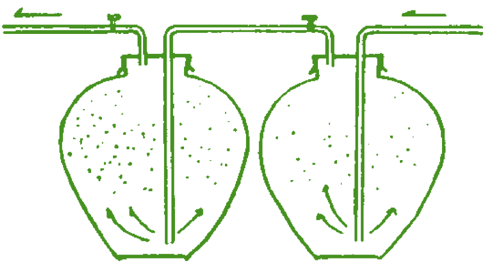
On the top section of a silo or granary, attach a 0.1- 0.2 mm layer of polyethylene film, installing a small pipe in the centre at the peak as an exhaust or ventilation pipe, which should be attached to an oxygen detector or to a carbon dioxide monitor. In this way, readings about the air inside the silo in terms of CO_2 or oxygen content can be readily obtained.

At the base of the storage pile or silo, a radial diffuser fitting should be placed and attached to a gas distribution pipe. A gas flow meter should be incorporated into this branch of piping, and in this branch should in turn be connected to a switch or control valve. Once the diffuser and pipes have been installed and checked for leaks and blockage, the methane gas valve can be opened, and gas added to the silo. Under the pressure provided by methane gas entering the base of the silo, air from within the silo will be forced out through the exhaust pipe at the top of the silo through the gas monitor and out into the open. Once a quantity of methane gas equal to 1.5 times the volume of the silo has been passed through in this way, and oxygen gas monitor verifies that the oxygen content has dropped to between 1 ~ 5%, or that CO_2 has reached 20 ~ 30%, then the ventilation pipe and valve at the base of the silo should be turned off. Left for three days, this will eradicate mealie beetles, weevils, and other similar pests, and will generally remain unaffected for up to one year.

■ Preventing Pests in Containers:

The methane grain protection technique is also suitable for household or other small sized containers, including porcelain jars, pots, crocks, barrels, and small cement pits. Generally, the containers are plugged with wooden stoppers or corks, with small holes that have been drilled to insert gas pipes. A gas 'input' pipe supplying the methane gas is inserted into one hole, and an exhaust pipe into the other. If there are many such pots, they can be connected in series i.e. the exhaust of one pot can be connected to the input of another pot. Small gas diffusers can be made from bamboo, connected to the pipe on the inside of the stopper, and placed in the bottom section of the pot. Once the pot or jar is full of grain, the stopper should be replaced and a small amount of paraffin wax or other sealant can be used to seal the groove around the stopper and top of the pot. A T-piece connector should be attached to the external end of the exhaust pipe, and a pressure gauge and valve added to the other ends, or even gas lamps and stoves. The first time that the storage vessel is flushed, the exhaust valve should be opened and connected to a burner, lamp or stove, and gas passed through the vessels until a flame can sustain the burner/lamp. The valve on the input and exhaust pipes should then be closed, and the vessels left sealed for 5 days, which will kill any insects in the grain.

Figure 16: Jars Connected in Series for Grain Storage Using Methane.



▪ Soaking Seeds:

Soaking seeds in spent slurry prior to germination develops overall more hearty plants. The process of soaking the seeds starts by first, placing fifteen to twenty kilos of seed in to a cloth/weave type bag with good water penetration qualities. Soak the bag in the discharge chamber of the digester, or some other vessel containing spent slurry, for approximately 48 ~ 60 hours (in the case of seeds with shells like rice), and for about 12 ~ 18 hours in the case of corn and other shell-less seeds. Finally, take out and wash, air, then following this process of accelerated germination, and sow the seeds in the ground as required. As a result of soaking in the slurry, rice germination rates are 5 ~ 10% higher than water alone, and approximately 20% more seeds reach seedling stage (than water soaking). Rice overall is more vigorous, it has better root growth, thicker stems and deep green foliage, a stronger response to transplanting and earlier budding. Yields can also increase by 5 ~ 8%. For corn, seeds sprout much earlier and yields can increase by 10 ~ 18% over standard sowing. Wheat germination rates increase by approximately 3% following slurry soaking, promoting strong growth of seedlings, with longer and more roots. In the same soil and conditions, yield from wheat that has been soaked (in spent slurry from the digester) will be about 7% higher than that for water alone.

▪ Using Spent Slurry and Sediment as a Fertiliser:

After filtering or sieving the slurry to remove large bio-solids, the slurry can be spread in early morning (around 8am ~ 10am). As much as possible, apply it to the back of leaves, as this helps the absorption of nutrients. Pay special attention to only apply an amount that is appropriate for the growth of the crop. If pesticides are to be mixed In with the slurry, this should first be done experimentally in a pilot plot.

Generally speaking, within 24 hours plants absorb 80% of the nutrients, resulting in improved photosynthesis performance and improved growth. It is also effective against some pests of selected crops. For example aphid populations can be reduced by more than 50% within forty-eight hours of application. Yields are generally enhanced, with more than 38% increase in grape harvests, 23% increase in apple harvests and a rise of 10% in rice and wheat yields, with an additional improvement in quality. As a general fertilizer, it improves fertility, and helps with production of environmentally sensitive 'green foods.'

Figure 17: Spent Slurry from the Digester Provides Farms with a Highly Effective Fertiliser

▪ Supplementing Pig and Fish Food:

Figure 18: Using By-products of Digesters to Raise Fish

An integrated system of a digester, pig sty, toilet and glasshouse efficiently utilizes each component to improve living conditions, and reduce the demand on purchased fuel and fertiliser. It also allows a family to raise fifteen pigs annually by constructing a plastic canopy of area 0.5 mu [Chinese unit of area mu (1/15 of a hectare)]. Spent slurry from digesters is a new type of feed supplement for animals. 'Mid level slurry' extracted the same day can be used to feed pigs according to weight. Generally, piglets under 25 kilograms would be fed 0.25 kilograms each sitting; pigs ranging from 25 to 50 kilograms would then be fed 0.75 ~ 1kg, and larger pigs 75kg and above should receive a 1.5kg supplement.

Figure 19: Pigs Raised Using Slurry from a Biogas Digester.

Appendix 1:

Human and Animal Average Daily & Annual Production & Recovery

Type	Weight (Kilograms)	Daily Manure (Kilograms)	Daily Urine (Kilograms)	Annual Production (Kilograms)	Recovery Rate (%)
Pig	50	6	15	2190	70
Cow	500	34	34	12410	70
Horse	500	10	15	3650	70
Sheep	15	1.5	2	548	70
Chicken	1.5	0.1	0	36.5	70
Human	50	0.5	1	182.5	70

Appendix 2:

Relationship between Fermentation Time and Temperature

Digester Temp (℃)	8	10	15	20	27	32
Time (days)	120	90	60	45	30	20

Appendix 3:

Gas Production Using the Semi-continuous Fermentation Technique under Standard Temperature Conditions

	Gas Production Volume (m^3/dry wt. ton)	Biogas Methane Content (%)	Energy Value of Dry Inputs Converted to Gas (kcal/kg)	Conversion Efficienc (%)	Fermentation Period (days)
Human Effluent	240-310	50	1200-1550	27-35	30
Pig Manure	330-361	65	1880-2060	42-47	60
Cow Manure	280	59	1540	35	90
Horse Manure	200-310	60	1100-1705	25-39	90
Sheep Manure	200	50	1000	23	
Chicken Manure	250	60	1375	31	

Note: The energy value calculated in the table is based on the methane content, the total energy content of the dry matter is approximately 4400kcal/kg. Energy conversion efficiency refers to the ration of energy content in gas produced vs. total energy content of the dry matter. Once the methane content of biogas has reached 50%, the energy content is approximately 5000 kcal/m^3. When the methane content of biogas produced reaches 60%, then the energy content is approximately 5500 kcal/m^3. If the biogas contains more than 70% methane, energy contained exceeds 6000 kcal/m^3.

Appendix 4:

Speed of Digestion using Common Input Types

Material	Production Speed (gas produced in period as % of total gas produced)			
	0-15 days	15-45 days	45-75 days	75-135 days
Human Faeces	86.0	14.0	0	0
Pig Manure	19.6	31.8	25.5	23.1
Cow Manure	11.0	33.8	20.9	34.3

Note: These results were derived under experimental conditions at a constant temperature of 30 degrees Celsius; Total gas produced as at 135 days was taken to be 100% of gas production.

Appendix 5:

Chicken, Cow Manure Production in Pig Equivalents

Manure	Pig Equivalent
30 Egg Laying Chickens (Laying Hens)	1 Pig
60 Hens (Broilers)	1 Pig
1 Dairy Cow	10 Pigs
1 Head of Beef Cattle	5 Pigs

Note: Manure production from five pigs is sufficient for a 10m^3 Separated Float Type Digester

Appendix 6:

GEI Yunnan Province Biogas – Crop Demonstration Agricultural Project

The Changsha (Yunnan Province) Biogas - Crop Demonstration Agricultural Project is an important part of GEI's Village-Based Sustainable Development Program. The Village-Based Sustainable Development Program provides China and other developing countries with a new mode

of development that is economically viable whilst minimizing the impact of development on ecological systems. This new mode of development is a product of the promotion of renewable energy (RE), organic agriculture (OA), and ecotourism (ET), in conjunction with the need for sustainable development promoted by expanded financial and market channels. It is an attempt to achieve a sustained improvement in rural living standards at the lowest possible ecological cost.

The Yunnan Changsha Biogas - Crop Demonstration Project uses a new kind of biogas technology. Under the direction of biogas experts from GEI, Changsha village constructed a group of five digesters or bays from 8 to 12 cubic meters. Based on the output, the new style of digester has obvious advantages in terms of rate of production. Presently, biogas is used primarily to satisfy the day to day energy needs of households and to provide a food supplement for animals. A new digester on average can reduce annual household expenditure on fuels like charcoal, coal and LNG by around 990 Yuan (Chinese Renminbi).

Under the direction of GEI experts, farmers in the Changsha area used spent sediment and slurry from digesters to grow organic vegetables and apples, with high yields. Digester sediment and slurry not only have appli-

Household Biogas Techn

ology

cation in reducing fertilizer costs, but can also raise yields and improve quality, whilst increasing soil fertility. Through organic farming, each household can increase its annual income by between 10000 to 18000 yuan (Chinese Renminbi), which is far above the local average income of 2000-3000 Yuan.

Local residents formed their own Biogas Service Association. The association is responsible for assisting local and nearby residents with construction and other services related to digesters. The association also sells sediment to other farmers who require fertilizer.

Households in the area of the demonstration project have not only received great benefits from the project, but more importantly, they have a new confidence in renewable energy. More and more peasants hope that biogas digesters can become their main source of income. Biogas is a realistic and clean path to financial success, whilst at the same time improving sanitation & health conditions, and protecting the environment.

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