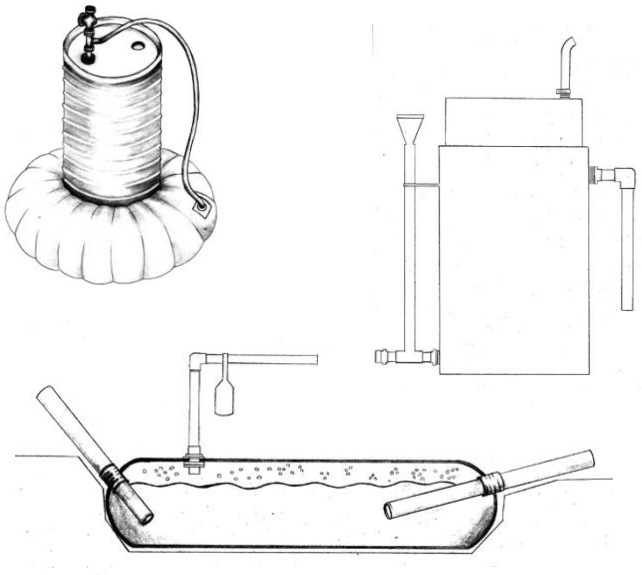
How-to guide

Making Waste Work: A Toolkit

How to convert organic waste into biogas

A step-by-step guide



How-to guide 3

Part of

Making Waste Work: A Toolkit

for community waste management in low and middle income countries

Zoë Lenkiewicz and Mike Webster
Illustrated by Susan Hatfield
October 2017

wasteaid.org.uk/toolkit

WasteAid UK is a charity working to make an impact on the global waste emergency by:

- Partnering with local organisations to improve the health, environment and livelihoods of people without waste services.
- Building the skills of local people to deliver practical solutions to the waste management crisis in their own communities.
- Raising awareness of the benefits of proper waste management and campaigning for greater change.

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3 How to convert organic waste into biogas

You can make a free cooking gas by digesting wet organic waste in a sealed chamber.

Summary: Place wet organic waste, such as food waste, in a sealed chamber with no air inside. As it digests, the waste will release a gas which can be captured and used for cooking. The system needs to be airtight and the temperature close to 35˚C.

Waste materials: Plant waste that is starchy, sugary or fibrous; fatty substances including animal fat or oil cake from oil seeds; flour swept from the floor of a flour mill; leftover and stale food; damaged or over-ripe fruits; insect damaged grain; non-edible rhizomes of banana or cane; tea leaves; animal dung, abattoir waste, and human excreta. If necessary the feedstock must be pulped or ground and mixed with water so it is like a soup.

There are lots of different designs of biodigesters. If you are planning to build one, it is best to read this entire chapter before starting, so you can better understand the technology and the important points to consider.

Product: After 14-21 days, the process will produce biogas and a nutrient-rich soil conditioner called digestate. About 1-1.5kg starchy material typically yields enough gas to cook the meals of 4-5 people. If the digester is working properly, the digestate will have little smell.

Benefits: Making biogas from organic material is a good way to manage potentially harmful organic wastes. Cooking with biogas does not produce smoke so it is ideal for the home, and it reduces the need to cut down trees for firewood. The digested slurry can be used wet or dry as a valuable soil conditioner, reducing the need for chemical fertilisers[1]. The benefits of using compost and soil conditioner are discussed in *How to convert organic waste into compost*, How-to guide 5.

Biogas is highly flammable. Make sure you have no naked flames or sparks near your biodigester.

Biogas can suffocate you in an enclosed space. Always make sure you work in a well-ventilated area and with at least one other person.

Animal dung contains bacteria, viruses and, possibly, parasites. When handling such material, use gloves and overalls and wash your hands afterwards.

A biogas plant needs some methane-producing bacteria to get it started. This is found in animal dung, so a small amount is used to start the process even if it is not the main feedstock. Once the system is producing biogas the bacteria reproduce and keep the process going.

[1] Do not use the slurry directly on plants. Add it to a compost heap first so that the heat can kill any disease-carrying bacteria.

Biogas essentials

The process is the same as what happens in a cow's stomach, where bacteria in the stomach convert food into a semi-solid material (dung) and biogas (a mix of methane and carbon dioxide).

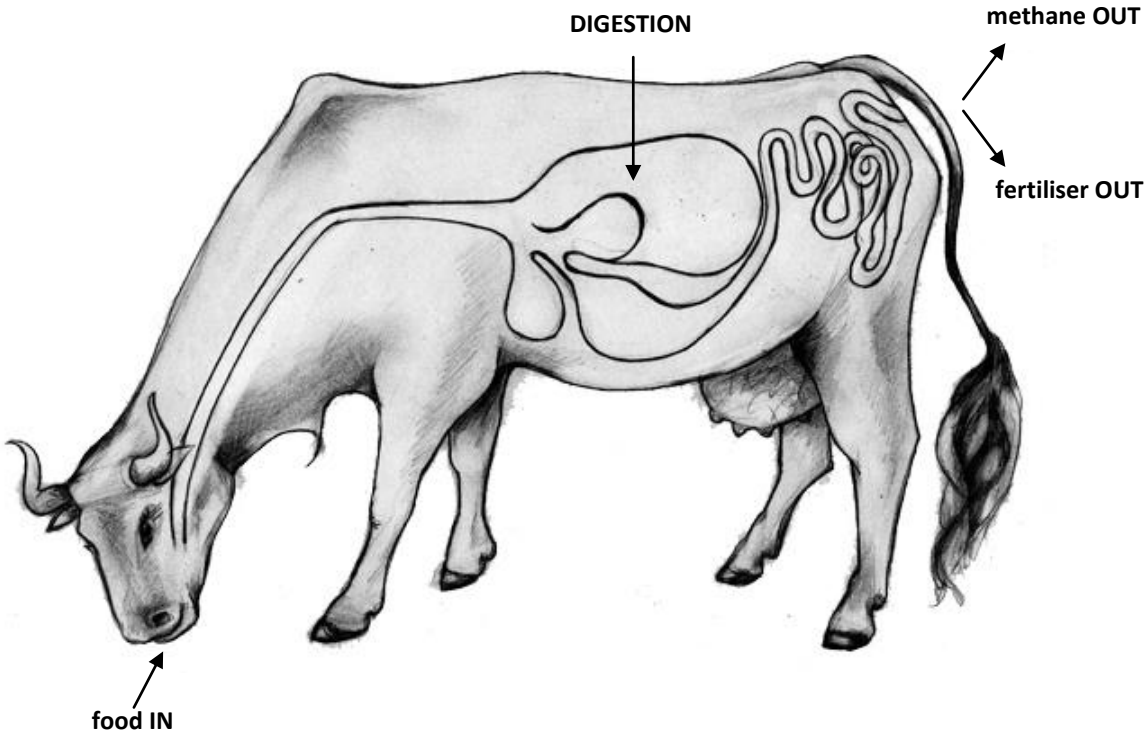


Figure 1: A biodigester works in a similar way to a cow's digestive process, producing methane gas and a semi-solid fertiliser.

It is possible to build family-size, community-size, and even very large industrial-scale biodigesters which serve entire cities.

Whatever the size and design, all biogas plants need:

- A large container to hold the mixture of decomposing organic matter and water (digester)
- A container to collect the biogas (gas holder)
- A way to add more organic matter (inlet)
- A way to move the gas to where it will be used (gas outlet)
- A way to remove the residue (slurry outlet)
- A way to insulate the container and keep it warm, unless the container is already in a tropical country with a temperature around 35˚C.

Larger underground masonry biogas plants can be more reliable than the cheaper, smaller-scale versions described in this toolkit, although specialist training is required. There are now about 45 million masonry biogas plants in China, 5 million in India, almost 400,000 in Nepal and another 400,000 in the rest of Asia (Bangladesh, Cambodia and Vietnam).

Typical biodigester designs

The most common type of masonry biogas plant is a **Fixed Dome Biodigester**.

The design combines the slurry container and biogas container in single chamber. As the slurry breaks down, it releases the gas, which rises to the top of the dome and can be piped away to a kitchen stove.

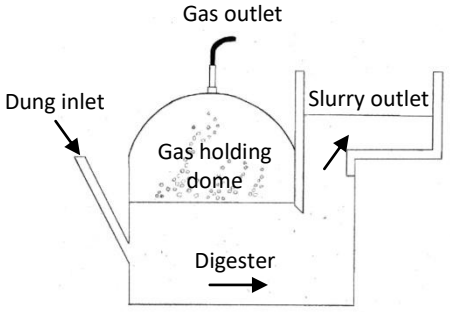


Figure 2: A fixed dome biodigester.

The other common type is a **Floating Dome Biodigester**, in which the gas container floats in the slurry. The gas container rises as the biogas is produced, and sinks again as the biogas is used.

The two designs described in this toolkit are based on the Floating Dome Biodigester. They have been selected because they are relatively low capital and are simple, popular designs if used on a small scale.

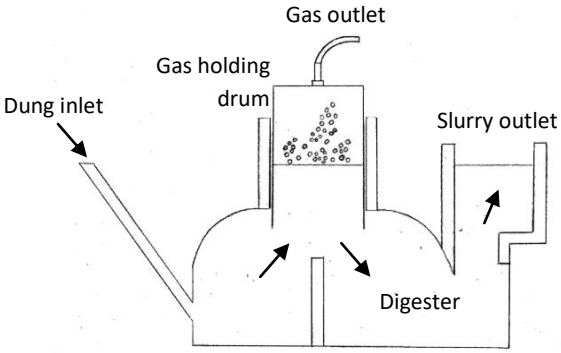


Figure 3: A floating dome biodigester

The **Tubular Bag Biodigester** sits in a trench in the ground. Biogas collects in the top of the flexible plastic tube and is piped away. See *How to build a tubular plastic biodigester*, How-to guide 3.1, for detailed instructions.

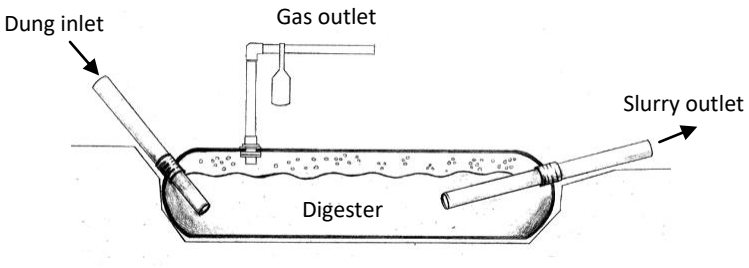


Figure 4: A tubular bag biodigester.

The **ARTI Floating Dome Biodigester** is made with a smaller container sitting upside down inside a larger container. The smaller container rises as it fills with biogas. See *How to build a floating dome biodigester*, How-to guide 3.2, for detailed instructions.

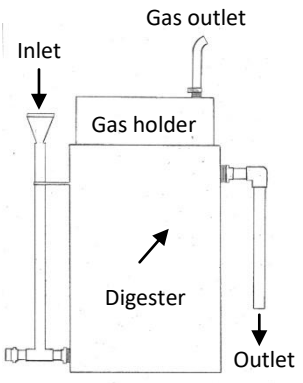


Figure 5: An ARTI floating dome biodigester.

Risk of fire and explosion

Methane, which makes up to 80% of biogas, can be explosive! This makes it a good cooking fuel but it also means you need to take extra care.

Do not use naked flames or anything that might spark (including power tools, normal electrical switches and static electricity) near the digester.

Asphyxiation

Biogas consists mainly of methane (CH_4) and carbon dioxide (CO_2), with low levels of hydrogen sulphide (H_2S) and other gases. Each of these has its own problems, as well as displacing oxygen.

- *CH_4 – lighter than air (will collect in roof spaces), explosive (see above).*
- *CO_2 – heavier than air (will collect in sumps), slightly elevated levels affect breathing, higher levels displace oxygen as well.*
- *H_2S – smells like rotten eggs, can be harmful to the nose and lungs, becomes odourless as the level increases to dangerous and fatal.*

High levels of hydrogen sulphide can kill.

Disease

Always wash thoroughly after working around the biodigester (and particularly before eating or drinking). Avoid contact with the contents of the digester.

Pathogens (disease carrying bacteria) are destroyed by heat, but there might still be pathogens in the digested slurry. Therefore it is advisable to re-use the effluent by mixing it with fresh feedstock and then pouring back into the digester. Alternatively add the slurry to a compost heap, where the heat will destroy any remaining pathogens.

Biodigester maintenance and troubleshooting

1. The biodigester needs maintenance and must be fed every day with organic waste and water. If you do not have enough feedstock to keep the biodigester working, consider collecting food waste or slurry from elsewhere.

2. Make sure you add enough water to the biodigester – the contents should be liquid, like a soup. However, if the soup is too thin, the solids and liquid will separate in the container and the digester will not work properly.

3. Do not use soapy water, pesticides or antibiotics in the mix. These will kill bacteria that generate methane gas.

4. Methane gas is produced when the pH level is 6 to 8.5 (alkaline). If the biodigester is over-fed it can become acidic, producing gas but no flame. If this happens, test the outlet slurry with litmus paper which is sold at most pharmacies. If your system is too acidic (with a pH level lower than 6), stop adding more feedstock, and then build up the feed rate slowly. Add more fresh animal dung to reseed the mix with the right kind of bacteria. This problem is more common with smaller systems (0.5 or 0.75 m^3) than with larger systems.

5. Biogas is produced best at a temperature between 25 and 37°C. When the temperature is below 15°C almost no gas is made. You can keep your biogas unit at the right temperature by insulating it.

6. Biodigesters do not kill all disease-carrying pathogens, so do not use the effluent (output slurry) from the process directly on plants. Instead, recycle the liquid by using it to mix the feedstock for the biodigester, or put it on your compost heap. The heat generated by the compost heap will destroy the pathogens.

7. If you can smell gas, check for loose connections, damaged taps or holes. Repair with sticking plaster or tape.

8. If not enough gas is produced:

    - Check for a loose connection, a broken section of pipe or a fold in the pipe stopping the gas flow. Replace any damaged sections of the hose pipe. Gas leaks are the most common problems in a biodigester. Great care must be taken to stop gas leaks, with good quality sealing materials.

    - Clear the water from the gas pipe. Do this by opening the joins and pouring out the water, or making a hole in the pipe, draining out the water and then covering the hole with tape.

9. Some biodigester designs need a water trap as a safety valve to prevent unsafe build-up of large amounts of gas. It is simple and cheap to make (see *How to build a tubular plastic biodigester*, How-to guide 3.1). Keep the water level topped up in the water trap: it will evaporate so will need topping up periodically.

Once the basic principles of generating and using biogas are understood, it is possible to create your own designs according to the materials and budget you have available.

The example illustrated in Figure 6 uses an oil barrel as the digester and a rubber ring to collect the gas.

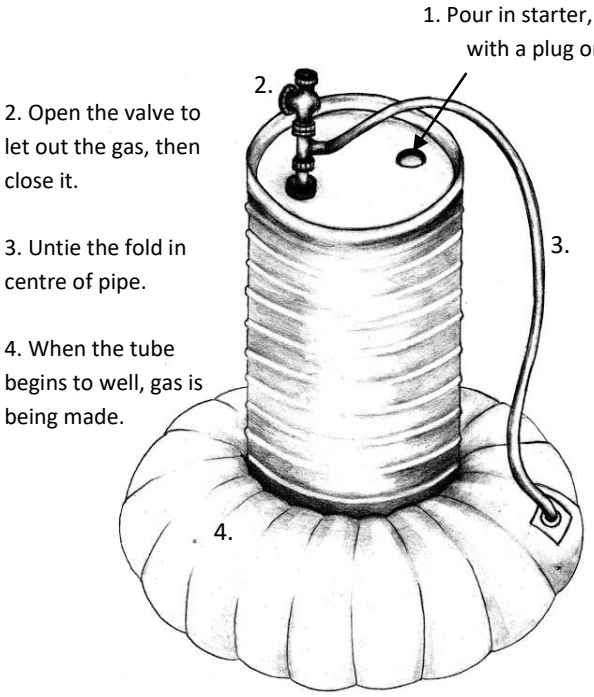


Figure 6: A simple design with rubber ring gas holder.

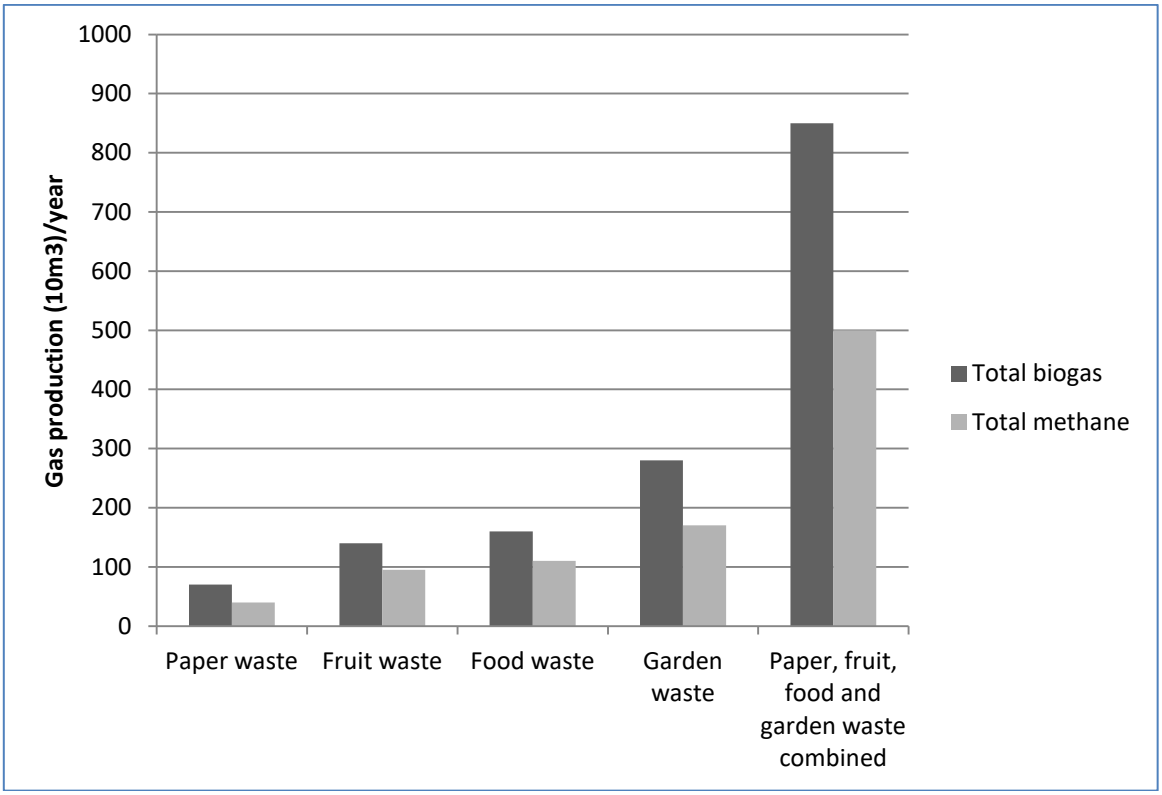


Figure 7: A bar graph showing the volume of biogas and methane that can typically be recovered from different types of organic waste in a tropical climate[2]. Biogas is a mixture of methane, carbon dioxide and other trace gases. Methane is the useful cooking gas.

[2] Getahun, Tadesse & Gebrehiwot, Mulat & Ambelu, Argaw & Van Gerven, Tom & Van der Bruggen, Bart. (2014). The potential of biogas production from municipal solid waste in a tropical climate. *Environmental monitoring and assessment,* 186.

3.1 How to build a tubular plastic biodigester

You can make a free cooking gas by digesting wet organic waste in a sealed chamber.

Before you start, make sure you have read all of* How to convert organic waste to biogas, *How-to guide 3.

Biogas is highly flammable. Make sure you have no naked flames or sparks near your biodigester.

Biogas can suffocate you in an enclosed space. Always make sure you work in a well-ventilated area and with at least one other person.

Animal dung contains bacteria, viruses and, possibly, parasites. When handling such material, use gloves and overalls and wash your hands afterwards.

The tubular plastic biodigester was developed by CONDRIT in the 1980s. It is simple and cheap to build, and there are more than 7,000 in use in Colombia, Ethiopia, Tanzania, Vietnam and Cambodia. The design described here was developed by Rodriguez and Preston, University of Tropical Agriculture Foundation, Vietnam, published by FAO[3].

You will need:

1. **Digester:** Transparent polyethylene (PE) tubular film, with a diameter between 80cm and 200cm (equivalent to a circumference of 2.5 to 6.3m). The thickness should be in the range of 800 to 1,000 (200 to 250 microns), although multiple layers of a thinner material can be used. The length of the tube is determined by the size of the biodigester (see calculations in Step 1). The most appropriate material is that which is used for greenhouses as this usually contains an ultraviolet (UV) filter which helps to prolong the life of the plastic when fully exposed to the sun. If this is not available you can shade the biodigester from the sun using a simple canopy.
2. **Inlet and effluent pipes:** 2 PVC tubes of 75 to 100cm length and 15cm internal diameter; 4 used inner tubes (from bicycle, motor cycle or motor car) cut into bands 5cm wide.
3. **Gas outlet:** 2m of PVC pipe of 12.5mm internal diameter; 2 PVC adapters (male and female) of 12.5mm internal diameter; 2 rubber washers (from car inner tube) of 7cm diameter and 1mm thickness with a 12.5mm diameter central hole; 2 rigid plastic (perspex) washers of 10cm diameter and a central hole of 12.5mm. Although perspex is best, these washers can be cut from different sources such as old plastic buckets and other materials made from strong plastic.

[3] Photographic instructions can be found by searching online for: “Biodigester installation manual” “FAO”

4. **Water trap:** 1 transparent plastic bottle; 1 PVC elbow of 12.5mm internal diameter; 3 PVC "T" pieces of 12.5mm internal diameter; 1 tube of PVC cement.
5. **Gas reservoir (optional):** 4m length of polyethylene tubular film; rigid PVC “T”.
6. **Gas pipe to stove:** Plastic (PVC) hosepipe of 12.5mm internal diameter (the length depends on the distance to the kitchen).
7. **Fencing and shade:** It is very important to keep animals (and children!) from damaging the plastic film. A shade will prevent the plastic from degrading in the sun.

Step 1: Prepare the trench

1. Choose a location close to where the waste is produced, for example near to a livestock pen or kitchen. It is easier to use gravity to transport the liquid waste to the biodigester than to move it by hand.

2. Calculate the size of the biodigester (this example has a $4m^3$ liquid capacity). The standard diameters of polyethylene (PE) tubular film are 80, 125 and 200cm. Here we will use a diameter of 80cm which gives a cross-section area of

   $$0.4*0.4*pi = 0.50m^2$$

   On average 80% of the total volume in the tube corresponds to the liquid fraction, so to accommodate a liquid volume of $4m^3$ will require a biodigester with a length of

   $$4/0.80/0.5 = 10m$$

   The recommended dimensions of the trench which will hold a biodigester of the above dimensions are:

   Width at top 90cm; depth 90cm ; width at bottom 70cm; length 10m

3. Using string attached to four posts, mark out on the land the upper extremities of the trench (in this example, 90cm*10m). Dig the trench, making sure the sides and floor are smooth with no stones or roots that could damage the plastic film.

   Dig the floor of the trench so that it has a slope of about 2.5% from the inlet to the outlet (for a 10m long biodigester, this would be 25cm). Move all the unwanted soil away from the trench so that it does not fall in and damage the plastic during construction or use of the biodigester.

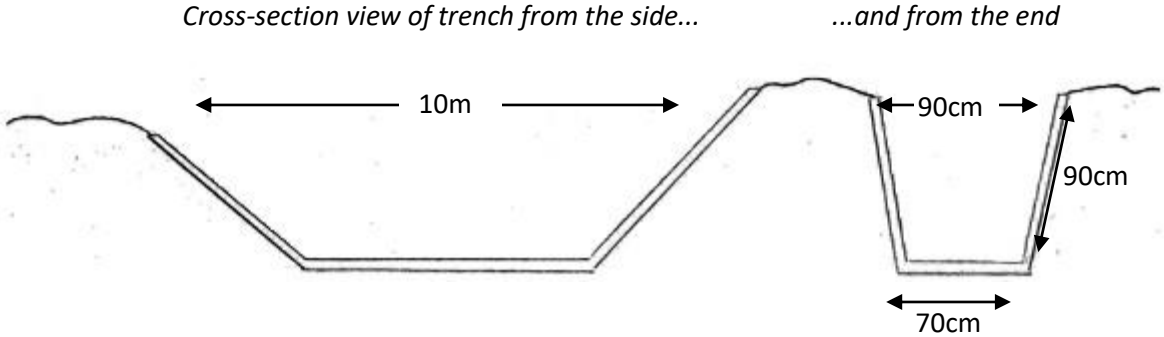


Figure 8: Cross-section views of the trench to dig for the tubular bag biodigester.

Step 2: Prepare the tube

The polyethylene comes from the factory in long rolls, so you may have a lot leftover which you could sell to other communities. A roll is also quite heavy (a 100m roll of 80cm tube weighs about 50kg) so be prepared if you need to transport it. Keeping a metal or bamboo rod in the centre of the roll makes it easier to unroll the desired length. Be very careful that the plastic sheet is not punctured when it is moved. If necessary, cut off and discard any sections that have holes in them. Even tiny holes can leak gas.

Measure out the desired length (10m in this example) and add 75cm onto each end for wrapping around the inlet and outlet pipes. The length in this example is therefore

10m+75cm+75cm = 11.5m

Cut two lengths and put one inside the other to give strength. Make sure they fit snugly together and that there are no folds or creases.

Step 3: Prepare the gas outlet

Mark the place where the gas outlet will be, about 1.5m from the end of the plastic tube and in the centre of what will be the top of the biodigester. Cut a hole the size of the external diameter of the PVC male adaptor.

Cut rubber washers from an old motorcycle or car inner tube. (Instructions for making washers can be found in How-to guide 3.2.)

Assemble the components, ensuring the male and female adaptors fit together smoothly.

Insert the male adaptor, complete with the plastic circle and rubber washer, from within the plastic tube. Then take the female adaptor, with the rubber washer and plastic circle attached, and screw it tightly onto the protruding male adaptor.

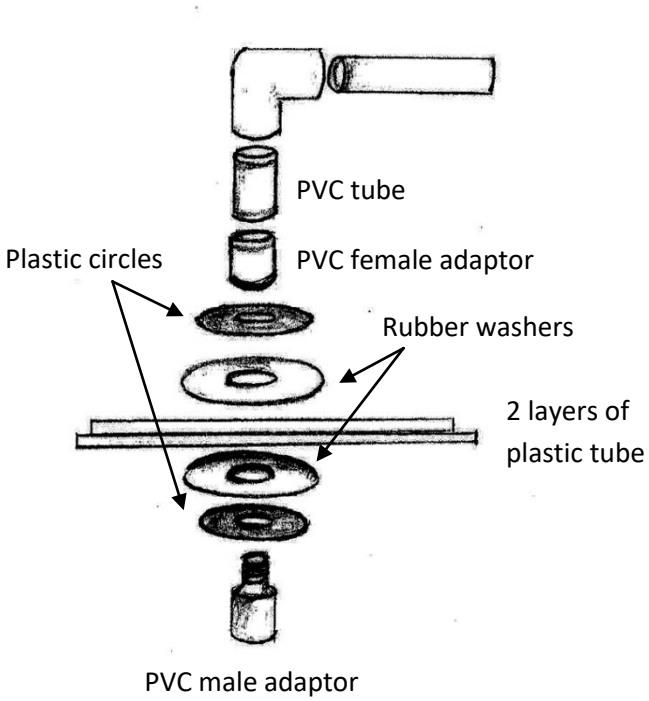


Figure 9: Prepare the gas outlet.

Step 4: Fixing the inlet pipe

Cut rubber bands 5cm wide from used inner tubes. Use protective sheeting on the ground below the work area to avoid damaging the plastic tube.

Insert the PVC pipe to one half of its length inside the plastic tube, and fold the plastic around it. Secure the join by wrapping the rubber bands around the pipe starting at 25cm from the edge of the plastic and working toward the exposed part of the PVC pipe, each band overlapping the previous one, and finishing on the PVC pipe so that the edges of the plastic tube are completely covered.

Step 5: Filling the plastic tube with air

Close the inlet tube with a plastic bag and a rubber band. Do the same to the gas outlet.

Fill the polyethylene tube with air before putting it in the trench. From the open end, force air into the tube by waving it up and down with your arms. Then tie the tube with a rubber band about 3m from the end so that the air cannot escape. This will make it easier to fit the outlet pipe, using the same process as for the inlet pipe.

Step 6: Fix the outlet pipe

Fit the second PVC pipe to the outlet of the plastic tube using the same procedure as for the inlet.

Make sure the edges of the plastic are completely covered by the rubber bands, overlapping each one, and ending on the PVC tube. Now close the end of the outlet pipe using a plastic bag and rubber band, and release the rubber band that was attached around the plastic tube. The bag will appear to deflate a little as air enters the end section that was previously closed.

Step 7: Final preparations

To completely fill the bag with air, attach a length (4m) of plastic tube (same material as used for the biodigester) to the PVC outlet pipe, filling this with air by the flapping procedure, and then remove the plastic bag sealing the end of the outlet pipe to allow this air to enter the main bag. Repeat this process until the biodigester bag is completely full of air. Reseal the outlet pipe with a plastic bag and rubber band. If the bag will not hold pressure, there is probably a hole in it and it may need to be sealed (see Hints).

Carry the inflated biodigester bag to the trench, making sure it does not get punctured by anything on the way. Lower the bag into the trench, with the gas outlet at the top of the tube. Prepare a support to hold the gas outlet line.

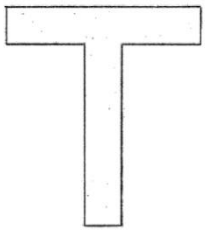
Secure the gas line (13mm internal diameter PVC tube) using PVC cement.

Fill the bag with water until the inlet and outlet pipes are covered with water from the inside. This traps the air inside the upper part of the bag. Remove the plastic bags over the inlet and outlet pipes.

Step 8: The water trap (gas escape valve)

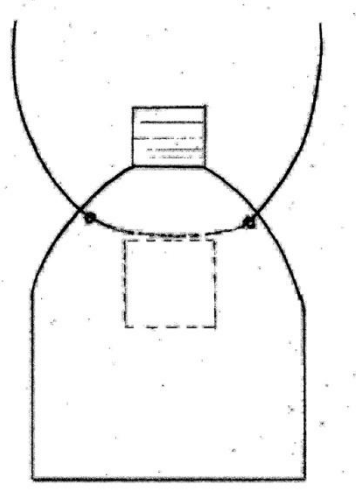
Fit a gas escape valve along the gas line. This is important as it prevents gas pressure building up to dangerous levels.

This simple but important device will prevent pressure building up in your system. Gas under pressure can be explosive.



Prepare a "T" from three pieces of PVC pipe, two short pieces and a longer one which will fit into a used plastic bottle.

Figure 10: A "T" shape made from connecting two pieces of pipe.



Cut a 3*3cm hole in the upper part of the bottle, just below the neck, through which water will be added to form the gas seal.

Make small holes either side of the neck to take a length of thin wire to attach the bottle to a support structure.

Insert the PVC "T" inside the bottle and add water to 4-5cm above the lower part of the "T". Punch small holes into the sides of the bottle 2cm above the lower end of the "T". This ensures that if the gas pressure inside the system exceeds 2cm water column the gas can escape to relieve the pressure.

Figure 11: An air hole in the top of the bottle with a wire to hag it to a support structure.

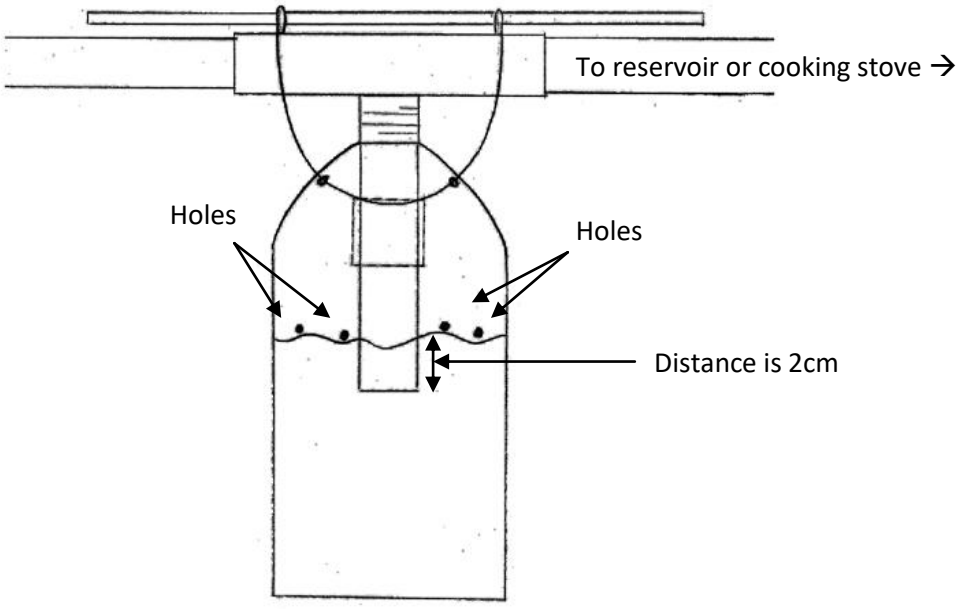


Figure 12: A completed water trap to allow the escape of high pressure gas.

Suspend the “water trap” in a convenient place so that the water level can be easily observed and replenished when necessary. Attach a flexible plastic pipe to the gas outlet and join to one arm of the other “T”. The other arm links with another plastic pipe which goes to the kitchen.

Step 9: The gas reservoir

Use a 4m length of the same polyethylene tube used for the biodigester. Close one end using rubber bands from used inner tubes. Fit a “T” made from rigid PVC to the other end. Locate the reservoir in a convenient place (for example, suspended in the roof space), close to the kitchen. Connect the arms of the “T” to the gas line; the inlet to the digester and the outlet to the stove in the kitchen.

(If you need to cook faster, you can increase the pressure in the reservoir by tightening the string around it. Remember to loosen the string after cooking so the reservoir can fill up with more gas.)

Step 10: Taking the gas to the kitchen

With the reservoir in place, attach the gas line from the outlet arm of the "T" to the stove.

Place a strap around the middle section of the reservoir. When you pull on the strap and tie it to a fixed object or a hanging stone or brick, you increase the pressure of the gas delivered to the burners. This is often necessary when cooking for a long time.

Depending on your feedstock, the biodigester should start to produce biogas within 5 to 28 days.

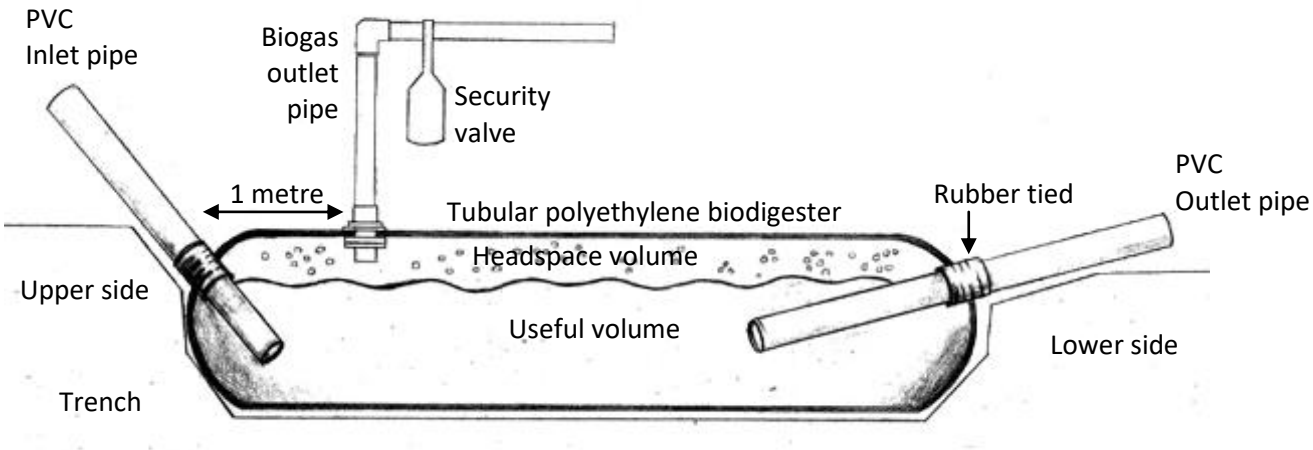


Figure 13: The tubular bag biodigester.

Hint: If the biodigester bags get damaged, patch the hole using male and female adaptors with washers big enough to cover the hole, and sealing the outlet of the adaptor. If the hole is too large to be mended, replace the plastic tubes and reinstall the system. Protect the digester with a fence to stop animals falling down. **Rats and other rodents like to bite plastic, so further protection may be required.**

Hint: If the slurry inside the biodigester becomes dry, replace the plastic tube of the biodigester. This is more likely to happen if you are feeding the biodigester with cattle manure. The bags will usually need to be changed every 2 to 4 years. Cut open the bags to remove the manure and mix with compost. Save a small amount to seed the new biodigester.

3.2 How to build a floating dome biodigester

You can make a free cooking gas by digesting wet organic waste in a sealed chamber.

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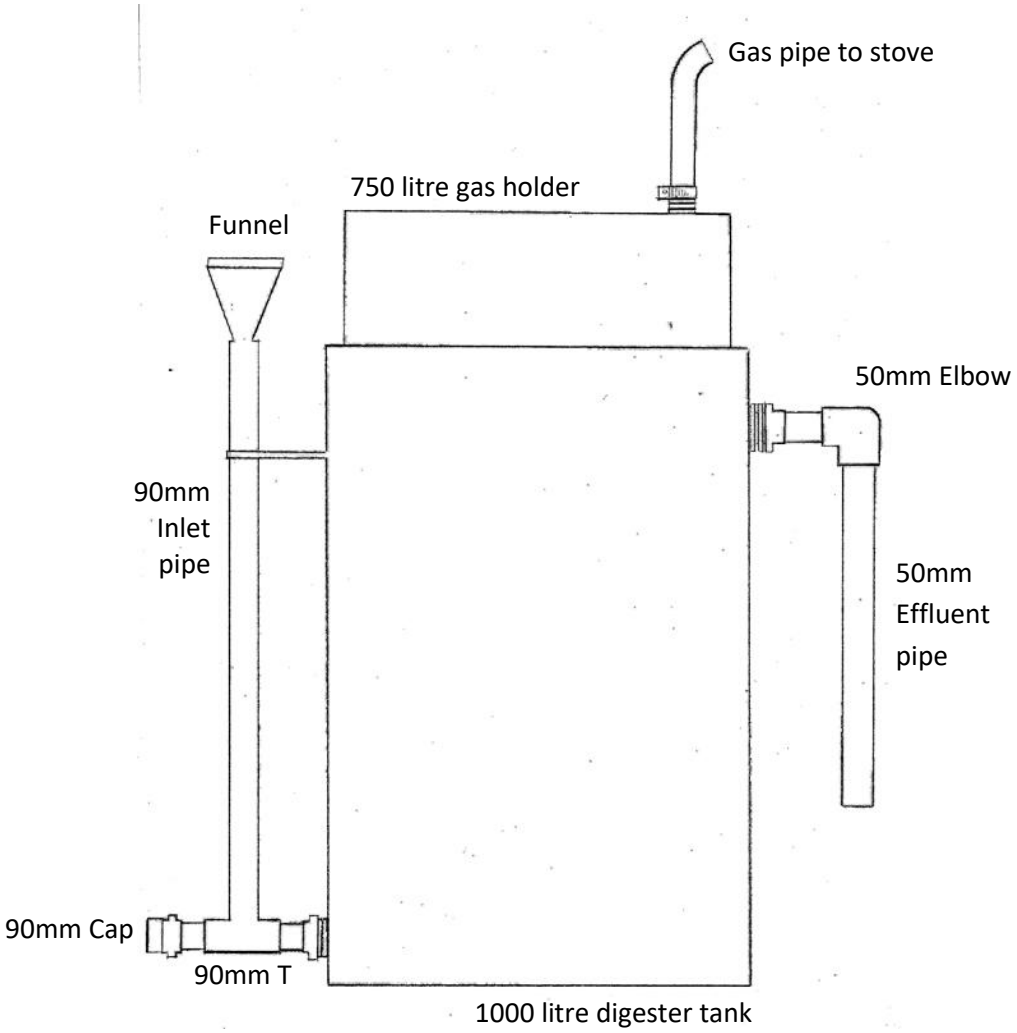


Figure 14: Floating dome biodigester.

This design was developed by Dr A.D. Karve of The Appropriate Rural Technology Institute (ARTI) in India. It is presented here with additional tips from EAWAG and AIDG[4].

Floating dome digesters: key facts *(from Ashden)***:**

- About 50 million household-size plants are in use, in China, India, Nepal, Vietnam and elsewhere. Over 10,000 larger plants are used for electricity generation.
- Household plants are typically 1 to 12 cubic metres in volume, with the largest commercial plants reaching up to several thousand cubic metres.
- The cost of household plant varies greatly from country to country, but is typically around US$550. If this cost is too high, a cheap alternative is suggested in *How to convert organic waste into* biogas, How-to guide 3. The techniques in this section, such as making your own washers, might be useful for incorporating into a simpler design.

[4] The Appropriate Rural Technology Institute (ARTI) www.arti-india.org; EAWAG www.eawag.ch; AIDG www.build-a-biogas-plant.com; Ashden www.ashden.org.

You will need:

1. 1000 litre plastic tank (digester).
2. 750 litre plastic tank (gas holder).
3. Sheet of rubber for making washers (this can be an old bicycle inner tube).
4. Chisel, jigsaw, scissors, pipe wrench.
5. Inlet pipe: a 90mm diameter pipe, a little longer than the height of the digester tank, fitted into a 90mm "T" at the bottom and fixed loosely to the top of the tank, in upright position. This pipe will also serve as a purge if necessary. Small block (of wood, brick or concrete).
6. Funnel: fix to the top of the inlet pipe to pour in feedstock material.
7. Effluent outlet: fitted at the top of the digester tank. (Collect effluent liquid and use it to mix with fresh feedstock, or put on your compost heap.)
8. Gas outlet: brass valve fitted to the top of the smaller inner tank and directed toward a gas stove. Flex hose and PVC pipe.
9. Frame structure: built above the tanks to stop the gas tank falling out when too full. It is possible to put a weight on the upper tank to increase gas pressure in the tank.

Step 1: Prepare

Cut the top of the big tank (the digester) so that the small tank (the gas holder) will fit inside it upside down. The big tank is cut so that its opening is the size of the small tank.

1. Cut off the top of the small tank and place it, centred, on top of the big tank to mark its perimeter.
2. Draw another cutting line 4cm larger all around, so that the hole is 8cm wider in total.

   (Alternatively, measure the distance from the centre of the top of the small tank to the outside with a piece of string and add 4cm to the length of the string. Place the end of the string on the centre of the top of the large tank and use it as a guide to mark a circle.)
3. Cut the tank using a very sharp and strong knife at first, and then with a handsaw or jigsaw blade. Test to see if the smaller tank fits well. It should have 4cm space around the sides. File the edges so they are smooth.

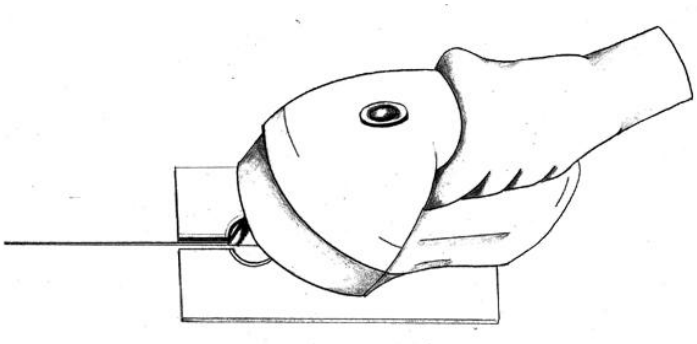


Figure 15: Cutting the plastic tank with a jigsaw.

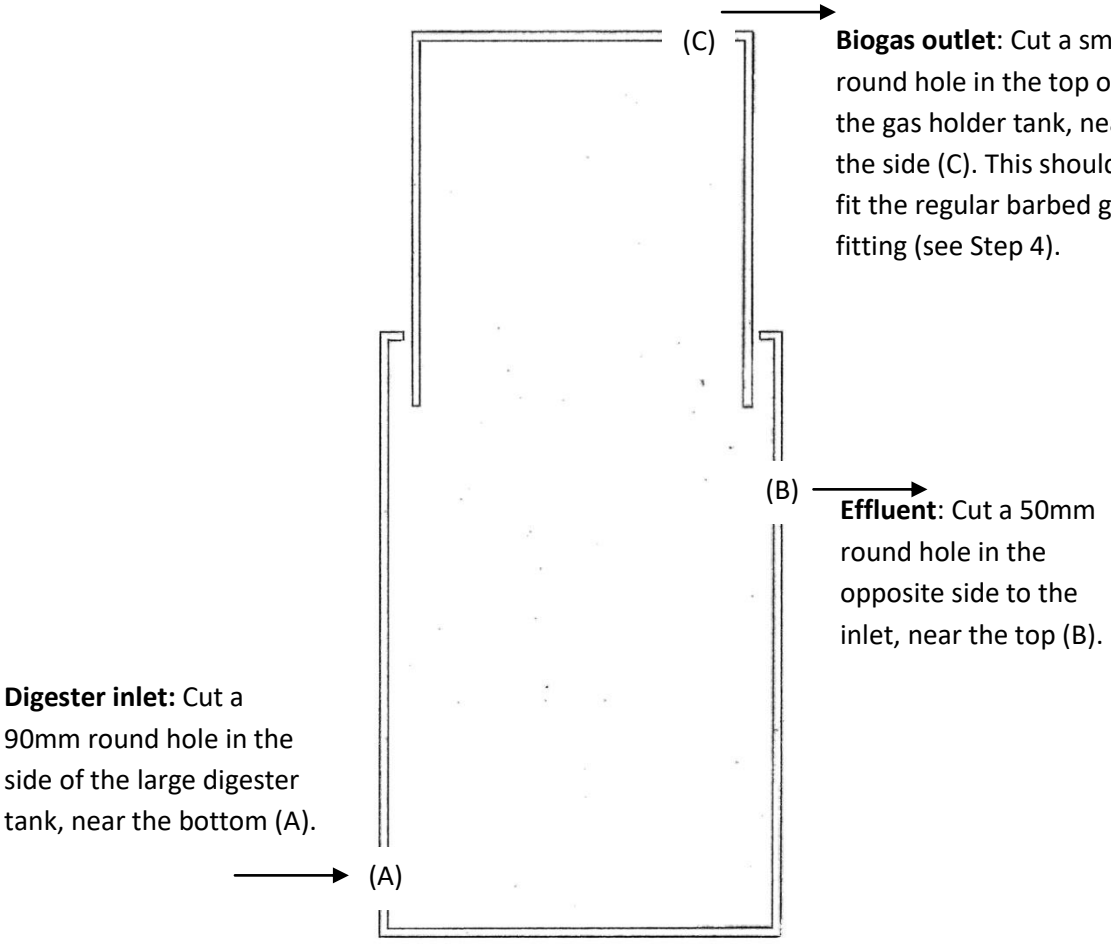


Figure 16: Prepare the tanks by cutting holes for pipe work.

Rubber washers: Make rubber washers to fit the pipe holes. Sit the pipe round end down on top of a sheet of rubber (this can be an old bicycle inner tube). Draw around the inside and outside of the pipe wall. Use scissors to cut the washer.

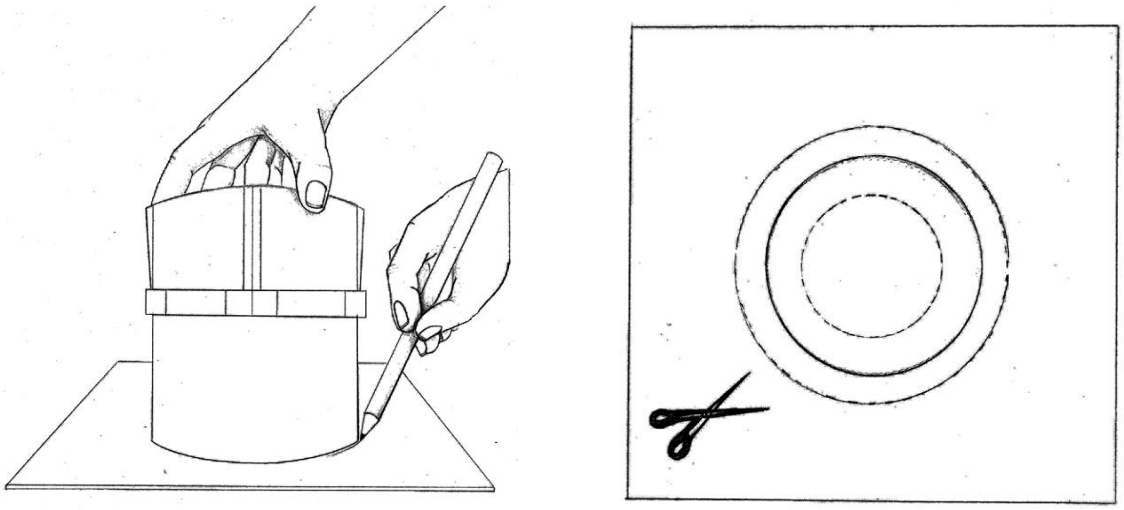


Figure 17: Make washers by cutting rings from rubber.

Step 2: Assemble and fit the inlet pipe

Fit 600x90mm pipe (A) into bottom of large digester tank (B) using an adaptor (C) to prevent leaks. It is helpful to push the end of the pipe through a block to keep it off the floor of the tank.

Fit 90mm plastic T pipe (D) in line, onto the outside of the fitted pipe. The cap (E) fits on the other end.

Fit the 1m pipe (F) onto the top of the T pipe so it stands vertically next to the tank. Attach (G) loosely to the side of the tank to stop it falling.

Fit the funnel (H) in the top of the vertical pipe.

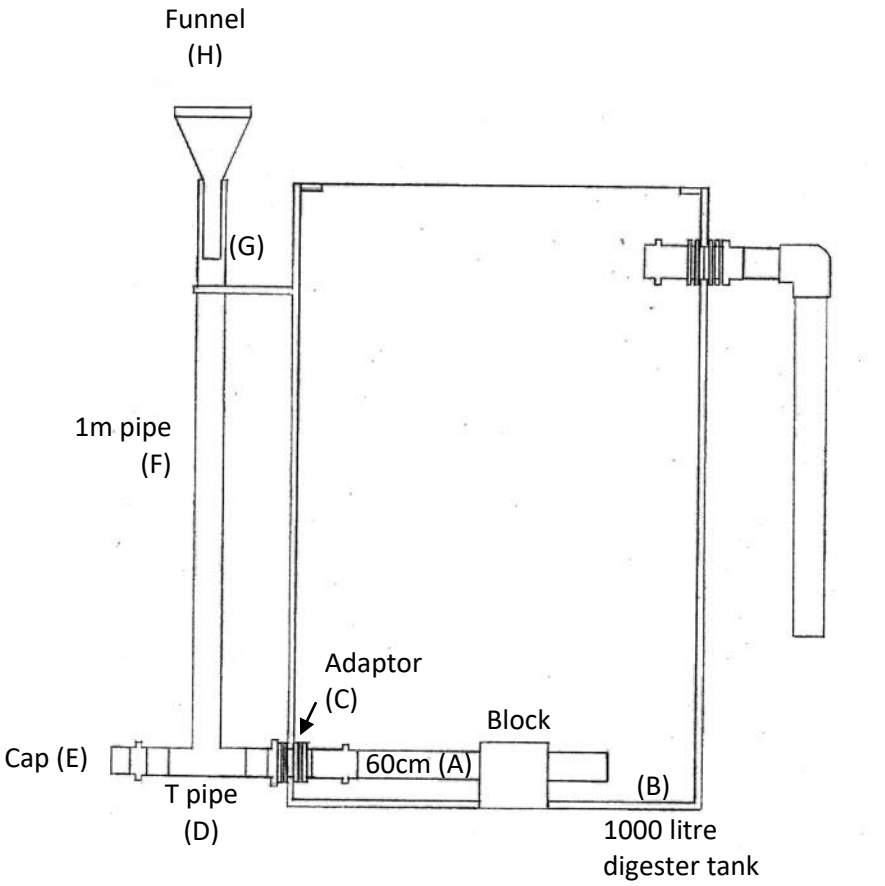


Figure 18: Assemble and fit the inlet pipe.

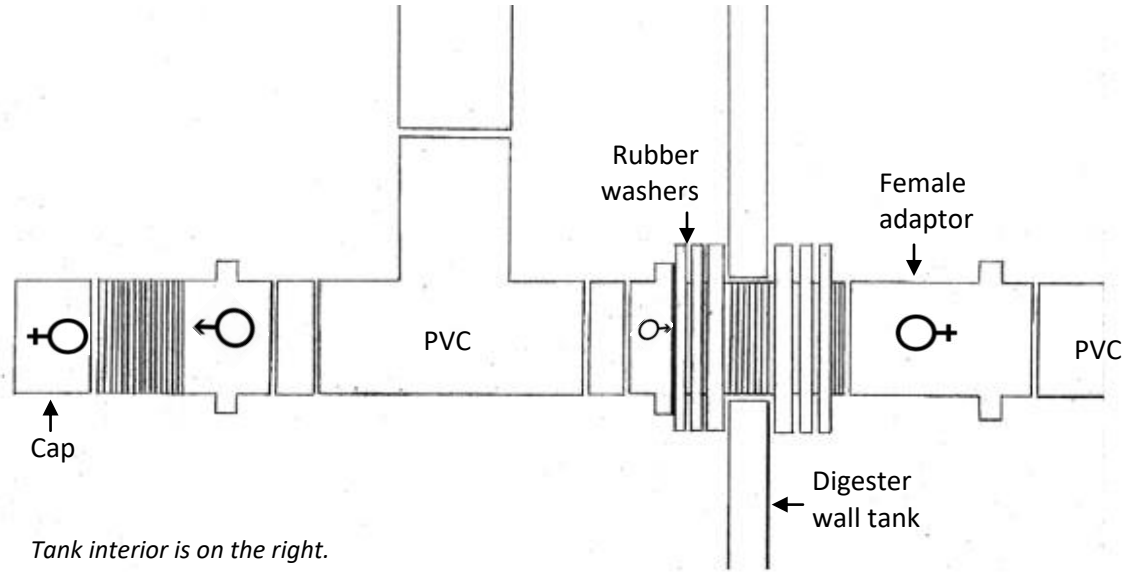


Figure 19: Assemble and fit the inlet pipe (detail).

Hint: The inlet needs to be watertight. Use a male fitting for this section and screw it through the tank wall using a pipe wrench. Then use 2 rubber washers and 1 thicker, spongier washer on each side of the inlet. Use silicon to seal all the joints.

Step 3: Assemble and fit the effluent pipe

Fit the 200x50mm pipe (I) into the side of the tank using an adaptor (J) to prevent leaks.

Seal the effluent outlet with washers on the inside and outside of the tank. Fit the 50mm elbow pipe (K) and the vertical effluent pipe (L) onto the end.

Hint: The length of pipe on the inside of the tank should be short, to allow enough space for the gas holder to fit inside the digester tank.

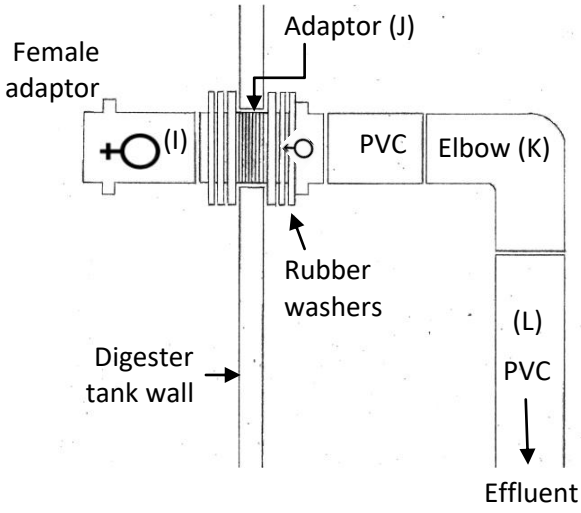


Figure 20: Assemble and fit the effluent pipe (detail).

Step 4: Assemble and fit the biogas pipe

Attach the gas line (A) to a regular barbed fitting (B) and secure with a hose clamp (C).

Sandwich the tank wall (D) between two washers (E) and (E) and nuts (F) on the threaded end of the fitting.

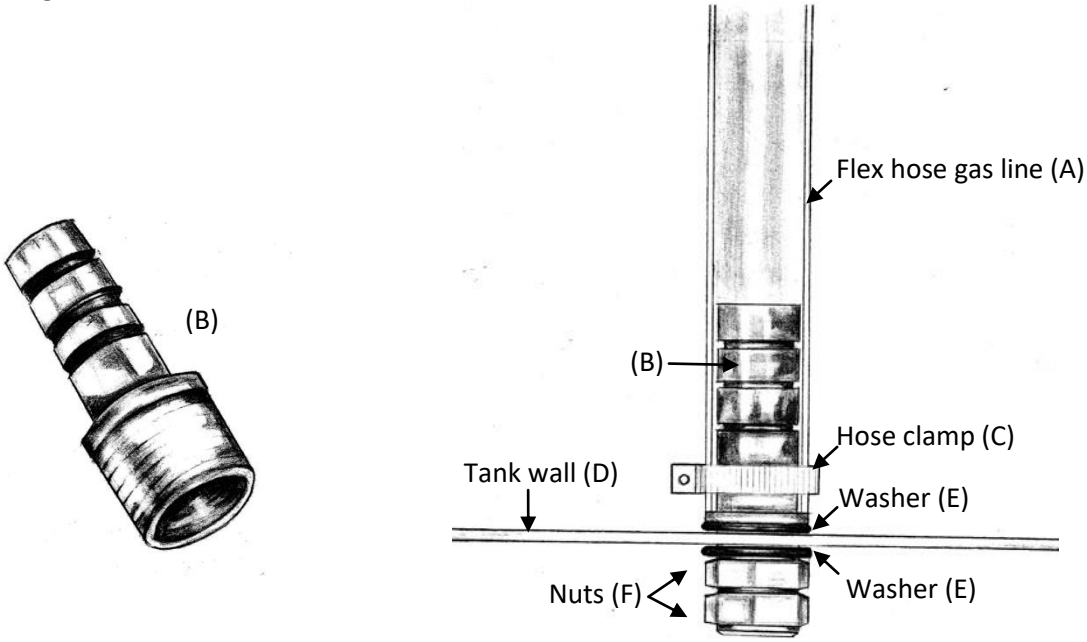
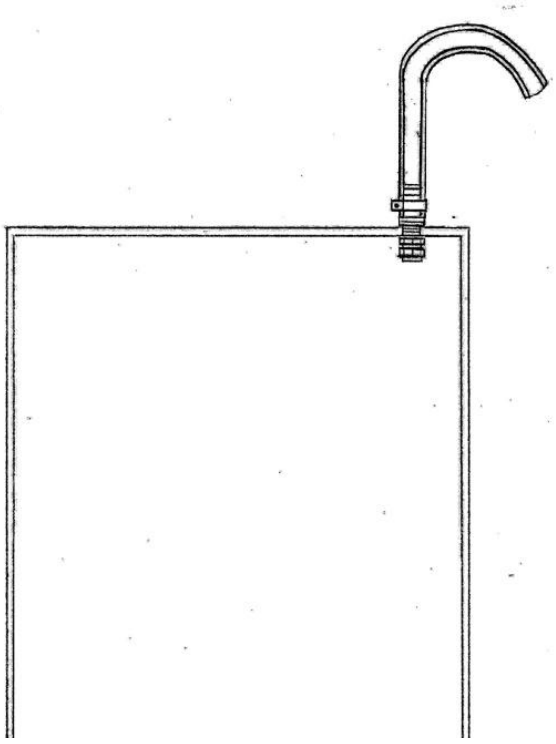


Figure 21: Assemble and fit the biogas pipe.



Hint: The gas line is a standard flex hose, which can be transitioned to a standard PVC gas pipe and buried underground. Burying the PVC line protects it from degrading in the sun and developing cracks that could cause gas leaks.

Figure 22: The gas line is a standard flex hose.

Step 6: Assemble the structure

Fit the gas holder (smaller) tank inside the digester (larger) tank.

To increase the gas pressure to a usable value, place a weight (for example a couple of bricks) on top of the floating drum. The height the tank rises will depend on the amount of gas in the holder. The pressure will vary very little as the tank rises. To make sure the gas tank stays in place, even when full of gas, use three lengths of 2cm PVC pipe connected together with 90˚ elbows to form inverted 'U' shapes (140cm, 129cm, 140cm.) Build two of these. Connect the two structures over the biodigester in an 'X' formation.

Step 7: Start the system

Start the system by loading it with about 20kg fresh cattle dung (not more than 6 days old), waste flour or starch and water. The bacteria from the cow's intestine, and consequently in the dung, are the bacteria that break down organic material into biogas (methane and carbon dioxide).

After 2 weeks, the system should start to produce gas and the upper tank will rise.

Test the gas by burning it: if it is combustible you can start to add high calorie material (see *How to convert organic waste into biogas*, How-to guide 3).

Step 8: Maintain the system

Each day, feed the system with 1-1.5kg feedstock mixed with 10 to 15 litres of water in the morning and again in the evening. Mash up any feedstock that has large lumps (of more than 2cm) so that it resembles a smooth soup.

The digester should provide a steady supply of gas, typically 250-500 g of gas per day from 1 kg (dry matter) of feed. Biogas is 1.15 kg / cubic metre, so to store this amount of gas would require a gas holder or reservoir with a 0.28-0.56 cubic metre capacity.

See *How to convert organic waste into biogas*, How-to guide 3, for maintenance and troubleshooting.

Step 9: Using your biogas

You may need to make adjustments to your gas burner to make the flame burn consistently. The methane / air mix is fairly critical, and this will vary depending on your feedstock. If the flame is yellow or producing black soot, increase the air so that the flame has more heat. More detailed designs for biogas cooking stove modifications can be found on the internet[5].

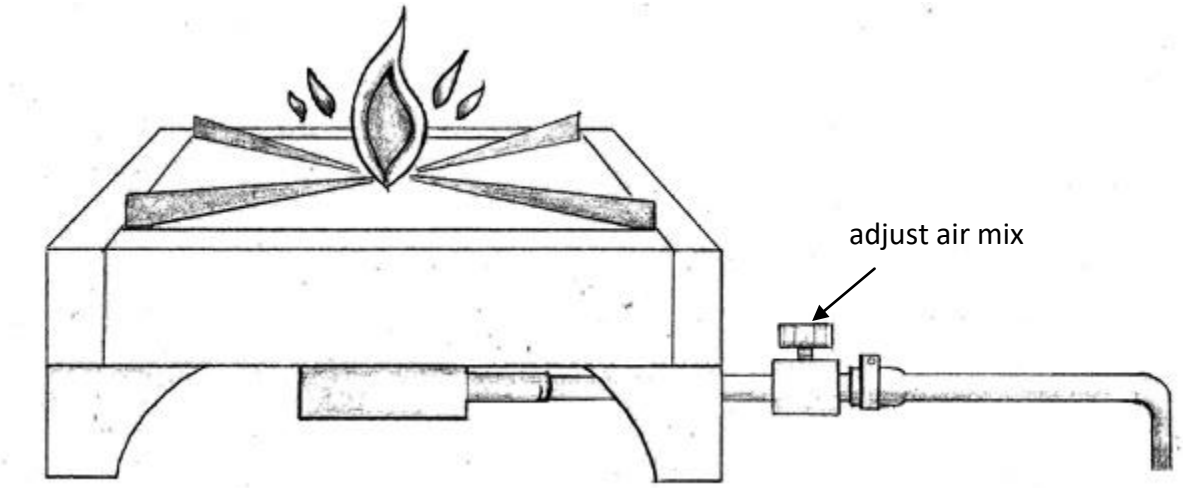


Figure 23: The biogas can be fed directly to a kitchen burner.

When your biodigester is working well, you should have enough gas every day to cook an evening meal.

Digester capacity	500 litres	1000 litres	2500 litres
Gas holder capacity	400 litres	750 litres	2000 litres
Available gas	250 litres	700 litres	1750 litres
Duration of burning	1 hour	2 hours	5 hours

Figure 24: The amount of gas generated from different size biodigesters (Source: ARTI).

[5] Fulford, D. (1996) Biogas Stove Design. Available at http://kingdombio.com/BiogasBurner1.pdf