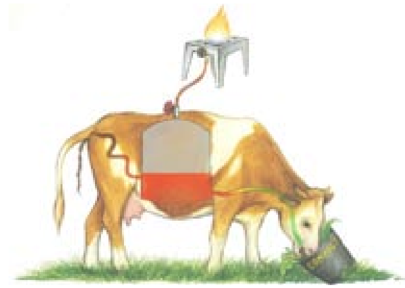

Biogas Digester

What is a biogas digester and how to build it?

Module for a decentral autonomous energy supply

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"Biogas" is a naturally occuring mixture of 60 to 70% methane and 30 to 40% CO_2 with some H_2S (Hydrogen Sulfide), that burns similar to so-called "natural gas", which is actually a fossil fuel.

Once generated and stored, biogas is primarily used around the world for cooking and heating at the home scale, but it also has many other important applications both domestically and industrially.

Its use as a fuel to power electric generators at all scales is well established and it also has a long history of use in gas lamps and absorption refrigeration systems.

When purified and compressed we see it used as an effective fuel for cars, trucks and buses (Stockholm-Sweden is a leader in this application). Thus biogas is a flexible substitute for non-renewable energy sources at many levels.

Additionally, its production creates a high quality fertilizer and provides feedstock for the creation of petrochemical substitutes so biogas serves to replace fossil resources on many levels.

A "biogas digester" is a simple system which produces biogas, via the natural anaerobic decomposition of organic material.

The biogas digester, once its "starter culture" of methanogenic (CH_4 producing) bacteria has been established (usually several weeks after initial loading with animal manures or lake mud) can be fed daily with kitchen and garden waste. The ecosystem of bacteria in the biogas digester extract energy from the organic material and generate methane gas.

The digested organic material exits the system as a high-quality fertilizer in liquid form. This liquid anaerobic "compost" still contains all the minerals and other soil nutrients of the kitchen and garden waste, including the nitrogen that can be lost through aerobic composting.

Construction and use of a biogas digester

Biogas systems can be built on any scale: small and simple for a single household, or large and industrial for a whole municipality. In Tamera we are interested in biogas digesters appropriate for a village or community kitchen; we strive to make these with inexpensive, widely accessible materials and technology.

As previously stated, biogas consists of about two third methane and one third CO_2, with some water vapor and trace gasses (principally H_2S) and as such, without any alteration or purification, it can be used in all appliances made for natural gas — for example cookers and water and space heaters and electric gensets — with minimal modifications.

A basic biogas digester consists of a tank in which the organic material is digested, combined with a system to collect and store the biogas produced. The digesters can be quite simple, and the details vary depending on available materials and the needs of the community.

Our biogas digester, built in cooperation with T.H. Culhane from Solar CITIES e.V., consists of a cylindrical 3000 liter tank, open on top, in which the organic material is digested. A second, slightly smaller tank is placed in the larger tank, upside-down.

As biogas is produced, the inner tank fills with gas and rises, telescoping out of the outer tank. As biogas is removed for use, the inner gas storage tank sinks back into the larger, outer tank.

In this system, the inner tank acts as both storage, and as a lid for the digester tank. The gap between the tank walls is narrow enough to prevent significant quantities of oxygen from entering the digester, which would kill the anaerobic bacteria that produce the methane.
The amount of biogas lost though the gap is negligible.

Tamera's 3000 liter digester is typically "fed" around 40-60 liters of biomass daily — a few full buckets of ground up organic waste mixed with water — and produces enough gas for several hours of cooking per day.

The main sources of biomass are food scraps and kitchen waste. Non-woody garden waste is also appropriate.

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Before being fed into the digester tank, the biomass is mechanically macerated — chewed up — with an “Insinkerator” garbage disposal.

Nowadays these “waste disposal” machines are being rebranded as “feedstock preparation devices” and we call them “compost companions” because they can be used to prepare organic garbage for use in both anaerobic and aerobic decomposition processes.

Grinding allows the bacteria to access and digest the organic material more easily; in an anaerobic system the transformation into gas and fertilizer can take as little as 24 hours while in an aerobic compost pile the transformation into soil can take as little as three to six days instead of months.

For our biogas digestor a slurry of ground biomass and warm (40°C) water is poured into the tank inlet funnel. The inlet for the digester leads down to the bottom center of the digester tank.

The digested organic material leaves as a high-quality liquid fertilizer, through an outlet near the top of the outer digester tank. At the top of the inverted, inner tank, there is an outlet for the biogas.

Before normal operation, the biogas digester must be “started.” This is done by preparing a 1:1 mixture of fresh animal manure and water, and allowing this to ferment anaerobically for several weeks.

The volume of this mixture should be around 200 liters for a 3000 liter digester or roughly 30-40 kg of animal manures per cubic meter of digestor tank space. Less can be used but it would simply take longer to establish the colonies of bacteria to enable feeding (feeding only starts once first flammable gas is produced).

The slurry can be prepared in a seperate container or in the digester tank. The manure contains the naturally-occurring bacteria that digest organic matter and produce methane. Note that unlike in cheesemaking or yoghurt making biogas digestors do not rely on one strain of bacteria but depend on a balanced ecology of many different types of microbes – hydrolytic, acidogenic, acetogenic and methanogenic.

Fortunately these are all found in animal manure and even lake mud. Essentially any animal wastes can be used — cow, horse, pig, and others; alone or mixed.

Human excreta can be used as well, although in this case the fertilizer output of the digester should only be used on trees, or in other appropriate applications.

Once the manure-mixture is producing flammable gas, feeding of the digester with biomass can begin. It is best to begin gradually, for example with 1/3 of the expected feeding for the first week, 2/3 for the second, and then onto a normal feeding regime.

The maximum ratio is about 25 liters of feedstock slurry for every 1000 liters of digestor space. During normal operation, manures can still be included in the feed stock. Most energy has already been extracted from manure, but it can help maintain or replenish bacteria populations in the digester and help balance the pH. The pH and temperature of the digester will affect its performance. Biogas digesters prefer to be at a neutral pH; overfeeding with fats and carbohydrates and certain acidic feedstocks can lower the pH and damage bacterial populations while overfeeding with proteins (animal or vegetable) or nitrogen-rich materials (for example chicken droppings, feathers, skin, hair or slaughterhouse waste) can raise the pH and also damage the bacterial consortia.

If one thinks of the digester simply as a stomach (for this is where the bacteria originated) and gives it a balanced nutrition, or if one thinks of it as a liquid compost pile and observes the usual C:N ratio of about 25 to 1, the system should last indefinitely. But if the bacterial ecology does get out of balance, one can simply restore the pH to neutral, add more manures, and start over, so it isn't difficult to recover from improper feeding and one shouldn't fret too much about "damaging" the system. Fortunately every one of us carries in our own guts all the materials we need to get things working again, and for this reason biogas systems are truly the easiest and most democratic of all forms of renewable energy.

High temperatures can kill bacteria; low temperatures may cause them to become dormant. Different methane-producing bacteria respond to temperature differently; some prefer cooler temperatures as low as 17°C-20°C (psychrophilic). Others thrive at higher temperatures around 57°C (thermophilic).

On the whole, however, biogas digesters well-suited to temperate climates work best at temperatures around 37°C (mesophilic).

In most non-tropical climates, it may be worthwhile to insulate and heat the digester tank, for example with a solar hot water system. It can be helpful to put lake mud in the digester to populate the colder bottom regions with psychrophilic (cold-adapted) microbes.

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The methane-producing bacteria are not adapted to floating free in a tank; they evolved to live in an animal's stomach, where they attach to surfaces while being exposed to flows of digestible material. These conditions can be recreated by covering the bottom of the tank with porous stones or gravel and by building high-surface-area "hi-rise" structures inside the digester tank (we call these "microbial motels"!).

Vertical structures which permit bacteria to inhabit all the temperature zones of the tank increase efficiency – water separates into thermal layers with the coldest water accumulating at the bottom of the tank and the warmest water at the top. Unfortunately, most biodigestors rely on bacteria living in sludge granules on the cold tank floor to do most of the work.

By providing bacterial "elevators" or vertical "fuel rods" we give our "pet microbes" a chance to find the zone within the thermocline most suited to their needs.

We often build our "microbe motels" with recycled plastic tubing, striving for minimum impact on the flow of gasses and slurry in the tank. We find verticle plastic pipes with holes cut in them to let food in and bubbles out to work well (think of a pipe organ) but vertically strung nets also work as does filling the tank with "bio-blocks" or "bio-balls" or other typical pond filtration media used to encourage bacterial growth.

One doesn't need to buy them – we make them by chopping up old corrugated plastic electrical conduit; in Palestine our colleagues throw in the husks of almonds and pistachios; the idea is simply to have floating media upon which bacteria can form their active biofilms.

The more surface area in the tank the larger your bacterial population and theoretically the more you can feed them; the more biofilms there are the more efficient the bacteria making them up can work and produce more gas and fertilizer (bacteria form what have been likened to "microbial cities" in their biofilms where different regions engage in specialized functions).

As Dr. Anand Karve, inventor of the ARTI India Telescoping biogas system we have adapted, said: "after all, we are talking about bacteria for heaven's sake - bacteria that can be found anywhere and everywhere, even in our own stomachs!"

Construction manual of a biogas digester by T.H. Culhane

Here is the description of the system, the basic principles are very simple, use the things you find in your surroundings.

1. Cut the top off at a 2.500 liter water tank.You have now made the stomach of your “sacred cow”.

2. Drill 2” hole at bottom of tank and 1” hole at top of tank.

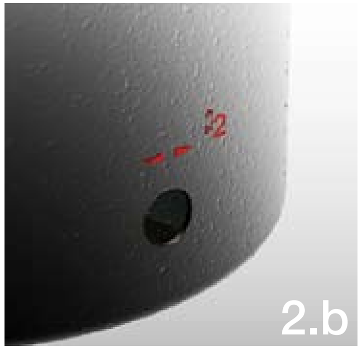
3. Put tank adaptors in holes (threaded pipe with rubber gasket and locking nut, sometimes called bulkhead fittings (check aquarium shop).

4. Fit 1” pipe in top hole (pic 4.a) on outside and 2” pipe inside tank that reaches to middle of tank.
Fit 2” tube outside tank to elbow going into tank. This is your feeding tube or the “throat of the cow” (pic 4.b-c).

5. Gas Collector. Take another tank that is smaller in diameter than the “stomach” tank you made (one that fits inside) but try to get one as close to the first tank as possible (for a 2.500 “stomach” tank you may only be able to find a 2.000 l “gas collector” tank. Cut holes in the bottom of this tank as shown (pic 5).

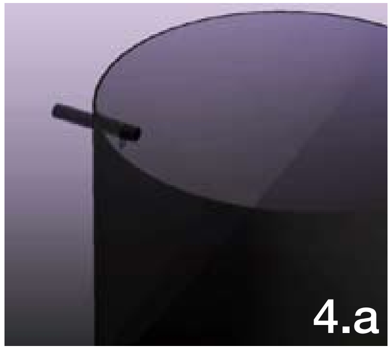
1

2.a



2.b

3



4.a

4.b

4.c

5

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6. Cut 8 holes slightly larger than 2” in bottom.

7. Burn or drill a ½” hole in the top of the gas collector tank near the side as shown.

8. Put a ½” tank fitting in this hole

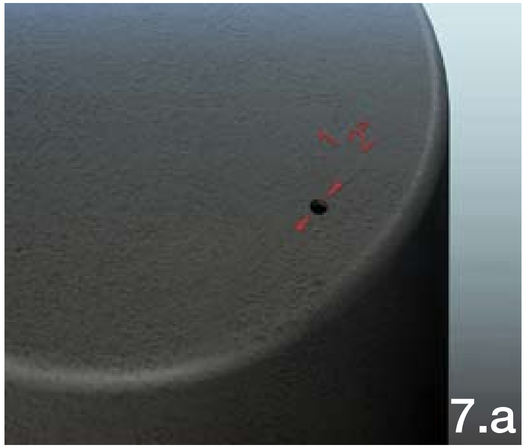
9. Put small stones at bottom of stomach tank as homes for bacteria, but do not block or go higher than the output of the feeding pipe.

10. Fill with about 300 to 500 liters of water (grey water is fine).
Then pour in about 100 kg of animal manure (this keeps the manure from being exposed to too much oxygen.
If you put manure in first you aerate it as you add water and that can kill bacteria. Bu sure and use fresh moist or wet fermented manure).
Fill the stomach tank to the top until some drips out the 1” pipe.

11. Cut 8 2” pipes slightly shorter than the height of the gas collector and cut holes in them like a church organ to let food in and gas out.

12. Fix a piece of ½” pipe (A) through one end of the 2” pipe and melt its ends so it flares out and can´t fall out of the 2” pipe.

13. Put the 2” pipe in the larger than 2” hole in the gas collector and when it is inserted, fix a ½” pipe (B) in the other end and flare it. Now



the 2” pipe can’t fall out of the tank when it goes up and down. Do the same thing for the other 7 pipes. These are our “bacterial motels” or bacterial fuel rods!

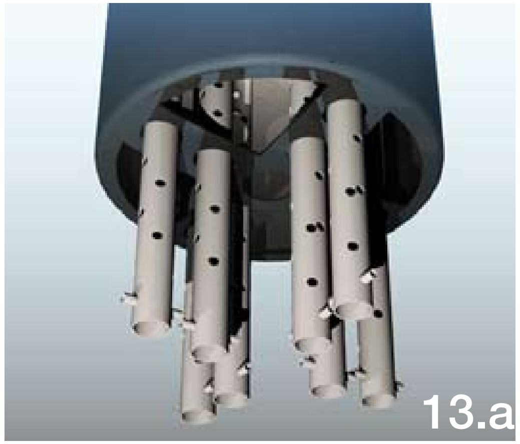
14. Place the gas collector in the stomach tank. Let it sink down until completely submerged if possible, making sure that the bacteria hotels are straight up and down (you may need to turn the tank slowly as you put it in and let the air out”.

15. Put an elbow, ½” valve and hose adaptor on the ½” tank adaptor and connect to ½” plastic tube.

16. Wait 3 weeks or so with valve closed until gas collector starts to rise. Release all gas to air and let it rise again.
Release all gas in case it has oxygen in it.

17. The third time tank rises, try to light gas coming out. If it doesn’t light it has too much CO_2 in it. Release it and let it rise again.
One day it will light as CH_2 concentration rises. Once it lights you can start slowly feeding.

18. When you connect the outcoming gas tube with your cooking place, make sure that a simple “water trap” is included, so that the pipes do not become blocked by condensing water.


13.a


13.b


14

Tamera

Healing Biotope I

Creating peace knowledge

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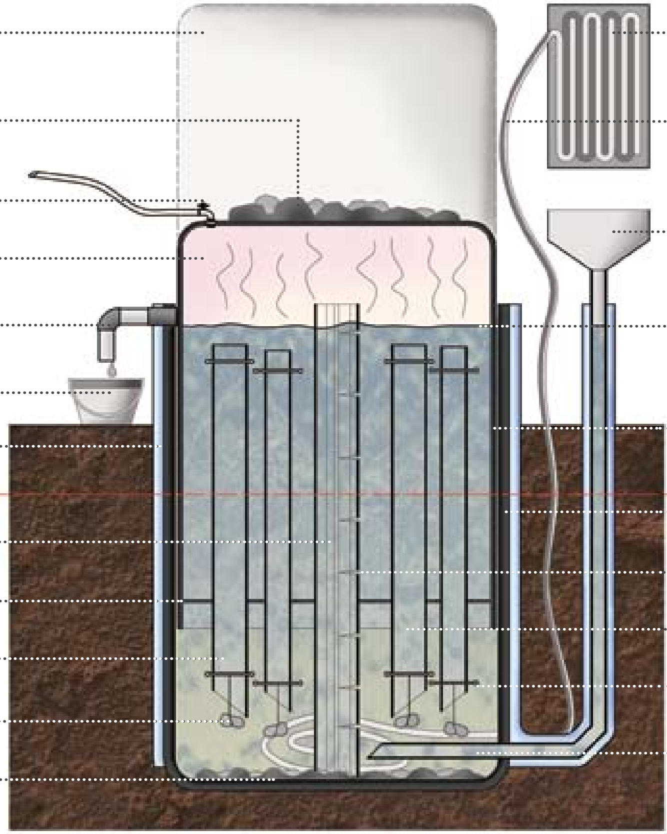
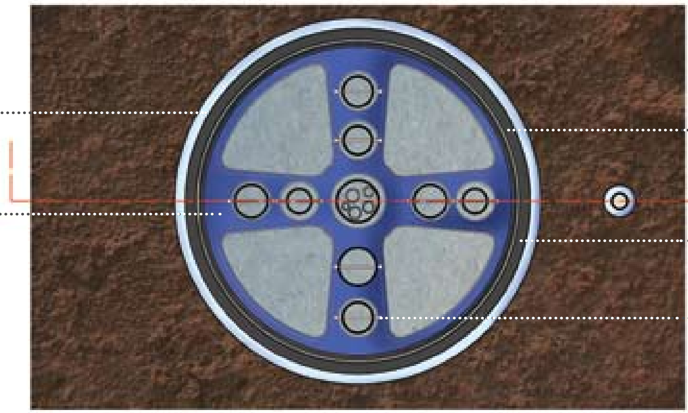


Vertical Section

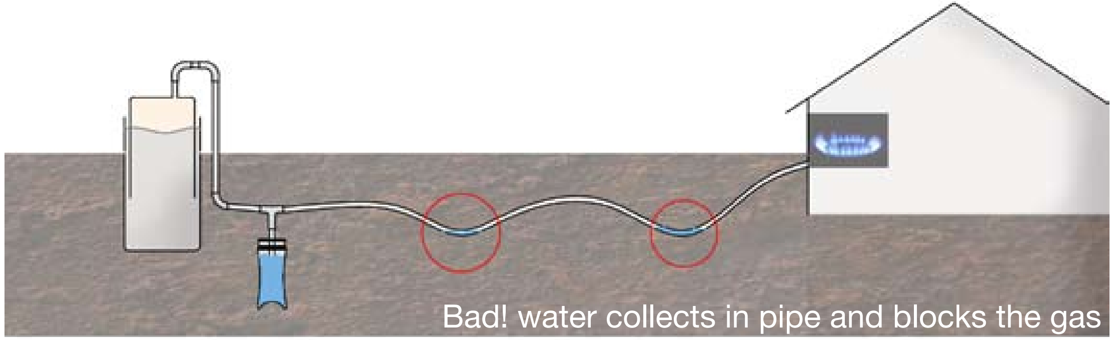
Horizontal Section

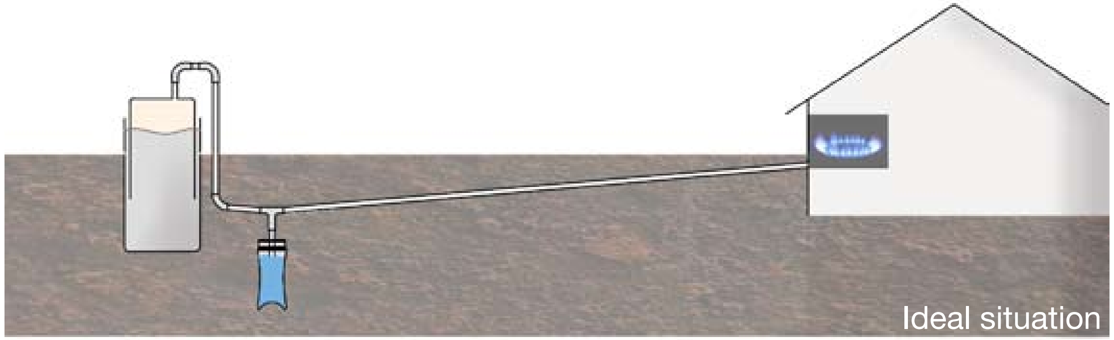


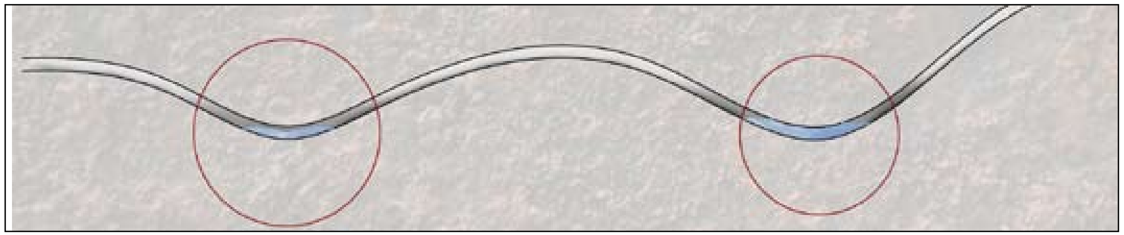
Scale 1: 100

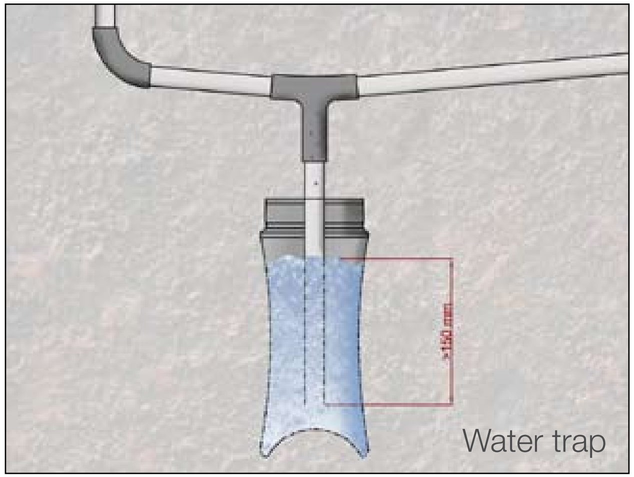
Pipeline Connection

Biogas naturally contains water vapor.
When it flows through a pipe, some of the vapor condenses as liquid water, and if it is left in the pipe, it will eventually collect and block the gas flow.
The solution is a water trap, a simple device which allows the water to escape.
It should be fitted to biogas pipes wherever there is a local low point of the pipe where water naturally collects.
And pipes should be laid so that these low points are at easily accessible positions.
The water trap consists of a T-joint running a short tube down from the main tube into a small container full of water.
The pressure of the water prevents gas from escaping. The water level should be approximately 15cm (equivalent to 15 mbar) to ensure no gas loss.
The container could be a plastic water bottle for example.
As it fills with water it will slowly overflow, so the location should be one where a small amount of water leakage is okay. An inspection hole in the ground, for example, works well.









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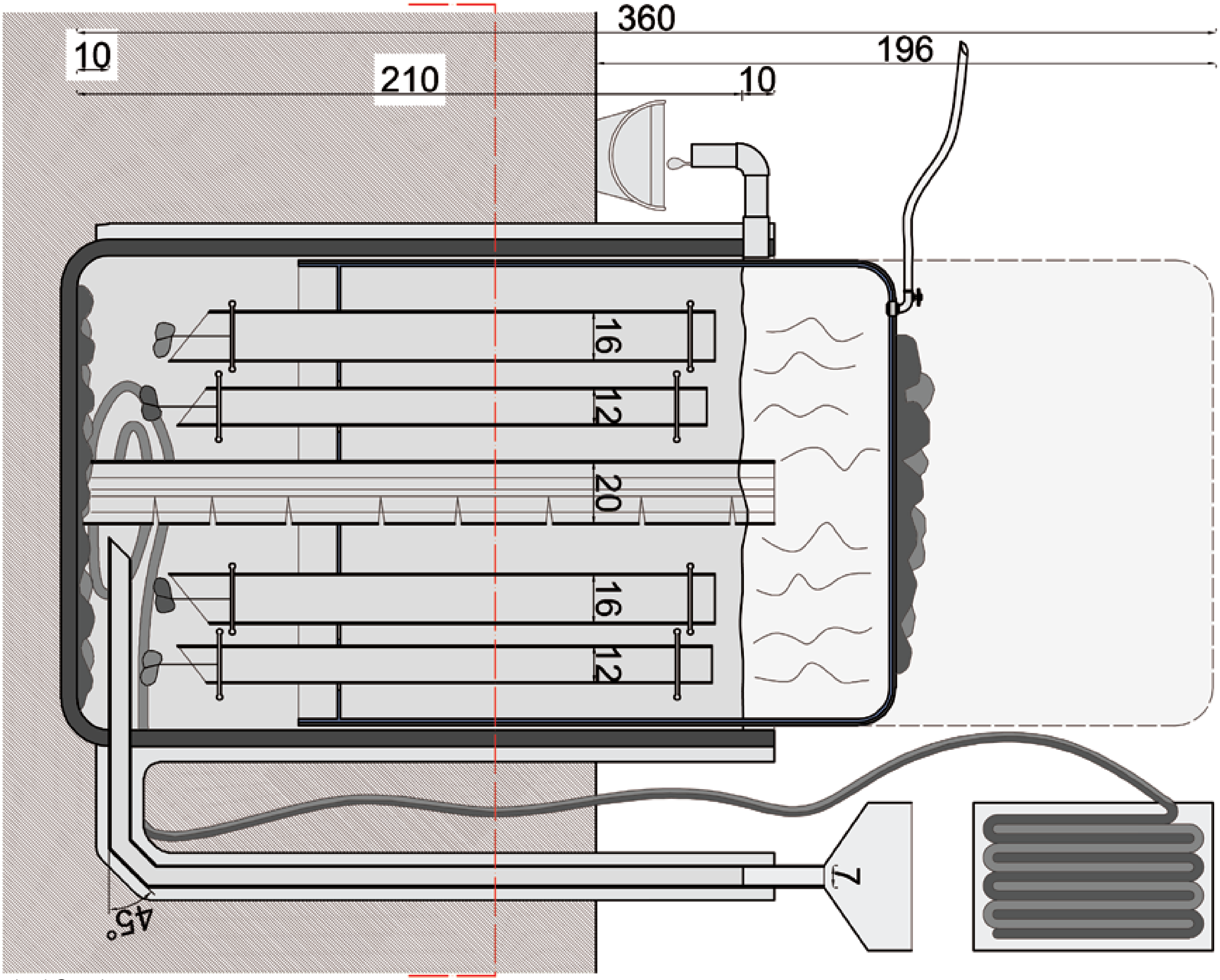
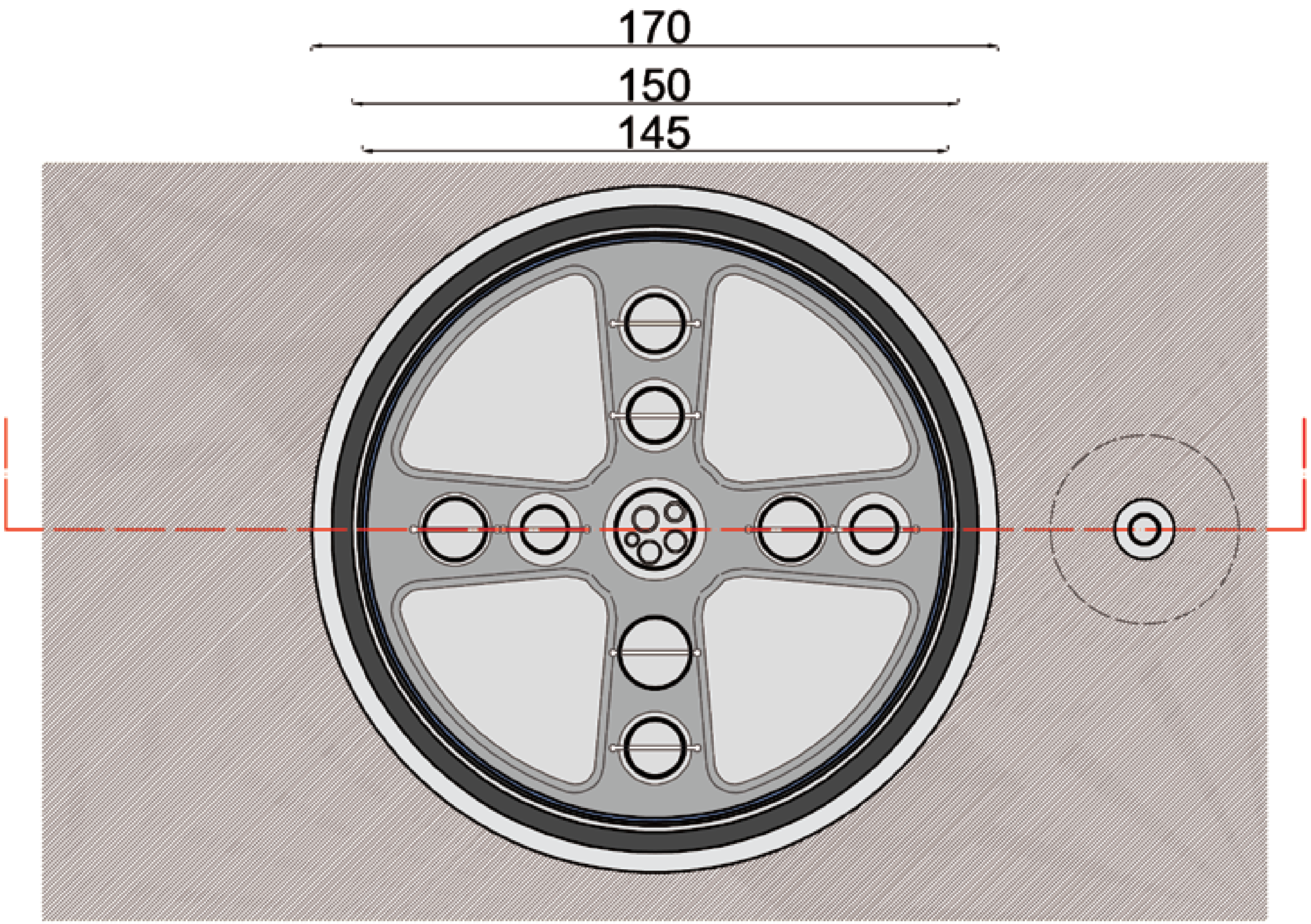


Vertical Section

Scale 1: 50



Horizontal Section

Scale 1: 50

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Picture of the biogas digester in Tamera

Here are pictures of the system we built in Tamera; we built it this way because these were the materials we could easily find. We used for the upper tank (gas collector) a 3.900 liter water tank, the bottom tank is made of concrete modules (parts of tubes used in construction), they fit into each other and are in our surrounding easily available.

excavation site

cut in the concrete

outer concrete tank

cuts on the central column

stones at the bottom of the tank

slowly fill the tank

mixture of animal manure and water

mixture

the tank is full

bacterial motels in the upper tank

place the upper plastic tank

fixing stones to keep the tubes down

place the upper plastic tank

place the upper plastic tank

kitchen and garden waste

backet with cutted compost

feeding the tank with compost

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