Biogas
Application

Agitation

The term 'agitation' subsumes different ways of homogenising the substrate or mixing it with water and co-substrate:

- Mixing and homogenizing the substrate in the mixing chamber

- Agitation inside the digester
- Poking through the in- and outlet pipes (small scale plants)

Agitation of the digester contents is important for the trouble-free performance of a biogas-plant. For the following reasons agitation is recommended several times a day:

- to avoid and destroy swimming and sinking layers
- to improve the activity of bacteria through release of biogas and provision of fresh nutrients
- to mix fresh and fermenting substrate in order to inoculate the former
- to arrive at an even distribution of temperature thus providing uniform conditions inside the digester

Even without mixing device, there is a certain agitation through the raising gas, through the movement of substrates with different temperatures and by the inflow of fresh substrate. This agitation, however, is usually insufficient. A well agitated substrate can, leaving other parameters constant, increase it's biogas production by 50%.

Agitation, as a general rule, should be performed *as much as necessary* *but as little as possible.* Too frequent mixing with fast rotating, mechanical agitation devices can disturb the biological processes in the fermenting substrate. In addition, an all-too thorough mixing of the whole digester contents may lead to half-digested substrate leaving the digester prematurely.

Mixing device in an agricultural digester under construction
Photo: Kraemer

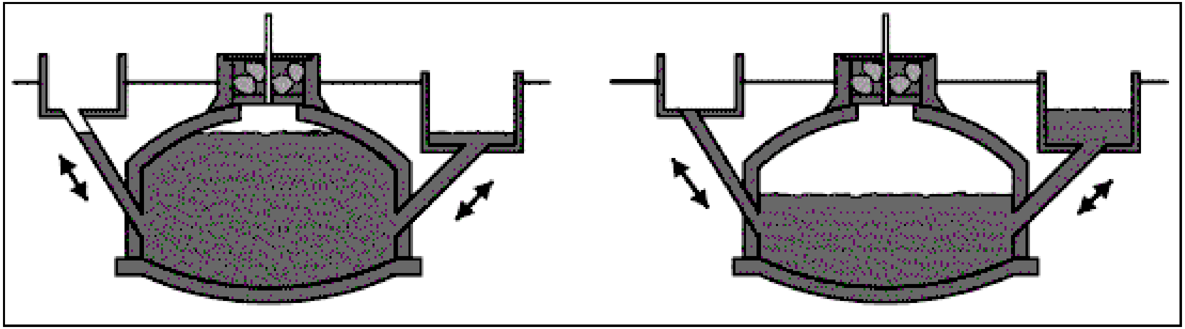
Mixing methods

Simple mixing methods have been installed mainly in developing countries:

- tangential inlet and outlet pipes
- separation walls
- forced substrate flow
- vertical hand-operated rotors
- horizontal, hand-operated paddle rotors
- poking through inlet and outlet

Mixing through inherent flow

In fixed dome plants, frequently found in developing countries, a certain mixing of the substrate is provided by the substrate being pushed up in the compensation tank with gas accumulation. When the stored gas is used, the substrate flows back into the digester.



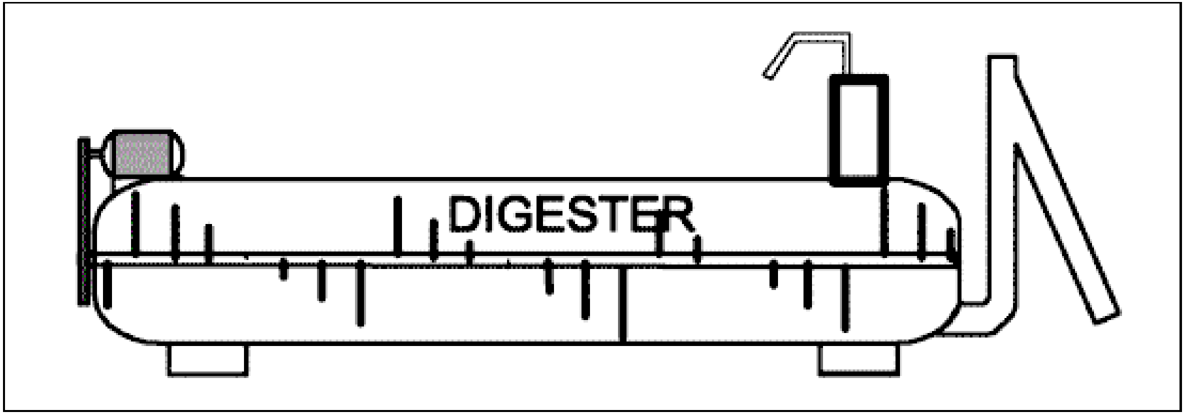
Mixing of substrate through inherent flow in fixed-dome plants
Source: TBW

The company "VSP-Anlagen" further developed and patented this principle:

Through the pressure of the biogas, the substrate is pushed from the main digester into the subsidiary digester, resulting in a difference of levels between the two digesters. By reaching a certain difference in levels, a gas valve opens between main and subsidiary digester which equalizes the height difference. The flow-back of the substrate is guided in a way that destroys sinking and swimming layers.

Mechanical paddle rotor

Mechanical paddle rotors are predominantly used in horizontal steel vessels. A horizontal shaft in hardwood bearings runs through the whole vessel. Attached are paddles or loop-shaped pipes. By turning the shaft the vessel contents are mixed, the swimming layer is broken up and sediments are pushed towards a drainage opening. The loop-shaped pipes can also be used as heat exchangers to warm up the substrate.



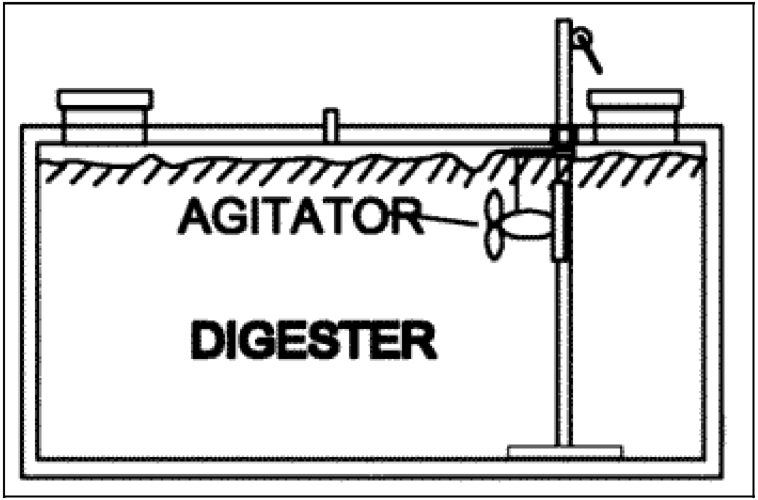
Mechanical paddle rotor

Source: TBW

Submerged motor with rotor

stirring

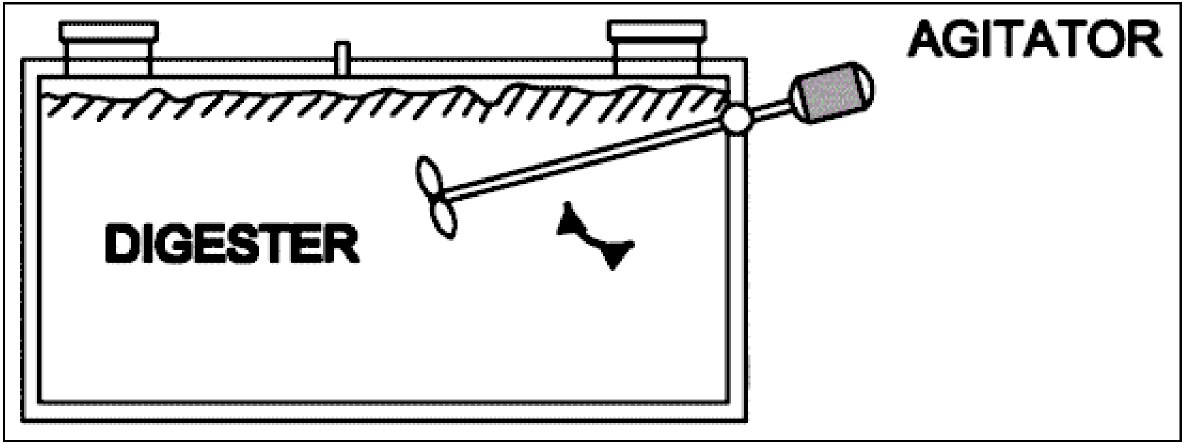
A sealed, submerged electric engine directly drives a rotor. The rotor mixes the substrate by creating a strong current. These stirring devices can usually be adjusted in height and in angle.



Submerged motor with rotor stirring
Source: TBW

Shaft-driven rotors

The mode of operation of a shaft-driven rotor is comparable to that of a submerged engine with rotor, only that the rotor is driven via shaft by an engine or by hand. The shaft should be movable in height and in angle to allow a mixing throughout the digester. The shaft should be long enough to reach both swimming and sinking layers.



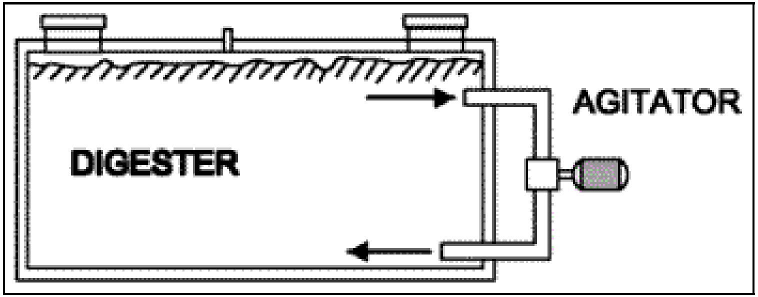
Shaft-driven rotor
Source: TBW

The rotor shaft can be inserted in two principle ways:

- Through the digester wall below the slurry level with water-tight sealing
- Through the gas-holder with gas-tight sealing

Hydraulic mixing

With a strong pump the whole substrate can be put in motion, provided the intake and outlet of the pump are placed in a way that corresponds with the digester shape. These pumps are often placed in a central position to cater for other tasks.

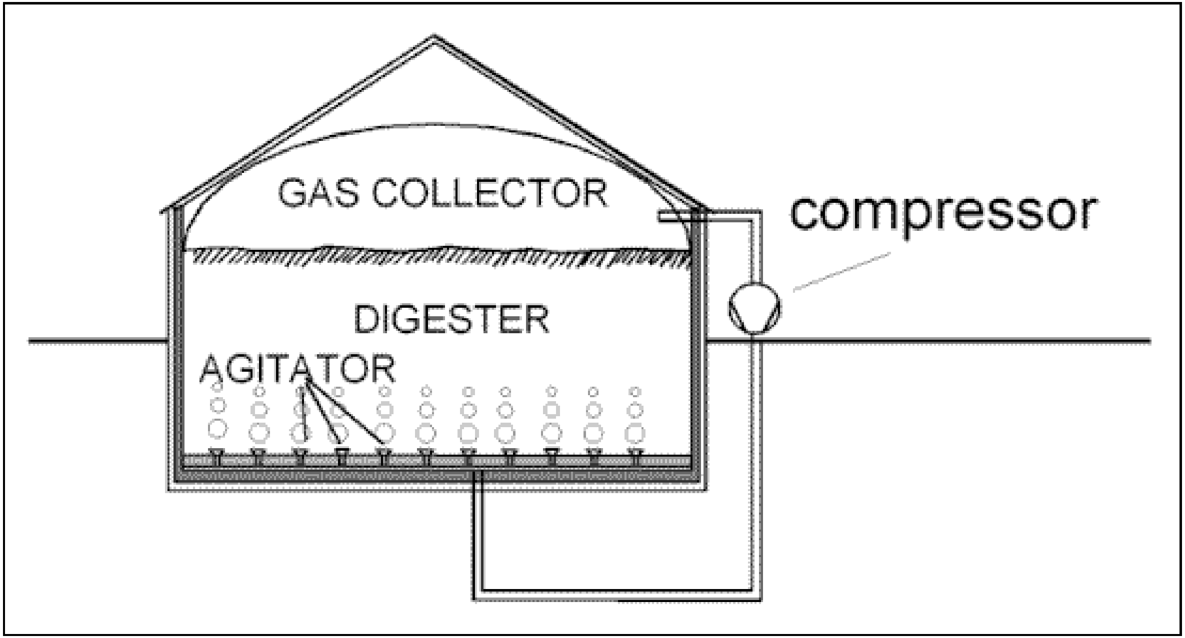


Hydraulic mixing

Source: TBW

Mixing through injection of biogas

A piping system with gas-jets is installed at the bottom of the digester. The raising biogas bubbles provide a gentle mixing of the substrate. The main problem with these systems is slurry entering into the piping system. This can be avoided by fixing pieces of elastic hose-pipe with stainless steel hose coupling to the jets.



Mixing through injection of biogas
Source: TBW

Hydraulic mixing by injecting biogas should not be used if the formation of swimming layers is a prevailing problem. Gas bubbles attach themselves to larger fibrous particles and lift them upwards, thus speeding up the formation of a swimming layer. Chopping up the substrate by means of chopper pumps or chopper rotors can only partly solve this problem.

Biogas
Application

Checklist for building a biogas plant

1. **Finishing the planning**, i.e. site evaluation, determination of

energy demand and biomass supply / biogas yield, plant sizing, selection of plant design, how and where to use the biogas, etc., in accordance with the planning guide

2. **Stipulate the plant's location and elaborate a site plan**, including all buildings, gas pipes, gas appliances and fields to be fertilized with digested slurry
3. **Draft a technical drawing showing all plant components**, i.e. mixing pit, connection to stabling, inlet / outlet, digester, gas-holder, gas pipes, slurry storage
4. **Preparation of material / personnel requirements list and procurement of materials needed for the chosen plant**:
    - bricks / stones / blocks for walls and foundation
    - sand, gravel
    - inlet / outlet pipes
    - metal parts (sheet metal, angle irons, etc.)
    - gas pipes and fittings

- paint and sealants
- gas appliances
- tools
- mason and helper
- unskilled labor
- workshop for metal (gas-holder) and pipe installation

5. **Material / personnel assignment planning**, i.e. procedural planning and execution of:
    - excavation
    - foundation slab
    - digester masonry
    - gasholder
    - rendering and sealing the masonry
    - mixing pit - slurry storage pit
    - drying out the plant

- installing the gas pipe
- acceptance inspection

6. **Regular building supervision**
7. **Commissioning**
    - functional inspection of the biogas plant and its components
    - starting the plant
8. **Filling the plant**
9. **Training the user**

Biogas
Application

Construction Details of Biogas Plants

This section provides detailed information on materials and devices used in the construction of biogas plants:

- Checklist for construction
- Agitation
- Heating
- Piping systems
- Plasters and Coats
- Pumps

- Slurry equipement
- Underground water

Biogas
Application

Heating

To achieve the optimum biogas yield, the anaerobic digestion needs constant environmental conditions, preferably close to the process optimum. The digester temperature is of prime importance. In temperate areas, a heating system and an insulation of the digester is necessary. Hence, the needed temperature for digestion can be reached and a loss of energy by transmission is compensated.

Because of the high costs for material and installation of a heating system, a low-cost biogas plant, as needed in developing countries, can only be build without heating. To boost the biogas yield for those plants, the building of a bigger digester to increase the retention time would be cheaper. A bigger digester reduces the required maintenance, while a heating system, increases maintenance requirements. A bigger digester serves also as a buffer for sediments, pH-variations and gas storage. For example, a fixed dome plant sized 50%

bigger, is only 10% more expensive.

The mean surrounding temperature and it's seasonal variations are very important. Biogas plants without heating system work, therefore, only in warmer regions for the whole year. In regions with extreme temperature variations, for instance in Turkey (hot summer, cold winter), the biogas plant should be built under the stable. Hence the biogas yield would be lower in summer, but constant over the year and at the end higher. Before implementation, at least an approximated average temperature profile and expected extremes over the year should be available for the site.

Heating system for a biodigester

A biogas plant with heating system and co-generation can be operated with process energy. Nevertheless the dimensioning of such a heating system is difficult, as the substrate, which has to be heated up, is not homogenous.

under construction (Germany)
Photo: Krieg (TBW)

A guiding figure for a digester with a hydraulic retention time of 20 days is 270 W/m^3 digester volume. The increasing of the hydraulic retention time makes it possible to reduce the heating power per volume. With a hydraulic retention time of 40 days the digester needs only 150 W/m^3.

Following figures are for heating systems with a heating water temperature difference of 20 K:

hydr. retention time	40 days	30 days	20 days
temperature difference	20 K	20 K	20 K
heating power	150 kW/m^3	210 kW/m^3	270 kW/m^3

A heating system located in the digester produces a thermal circulation, which is, especially for non-agitated digesters, very important.

An indirect energy transfer by heat exchanger is most common. Exceptions are steam injection, liquefying of solid manure with heated water and the heating by pre-aeration.

Internal and external heating systems

External heating systems have a forced flow on both sides. Due to the turbulent flow patterns of both media, a very good heat transportation can be reached. Therefore, the surface of the heat exchanger can be comparatively small. Nevertheless those systems cannot be recommended for non-agitated digesters.

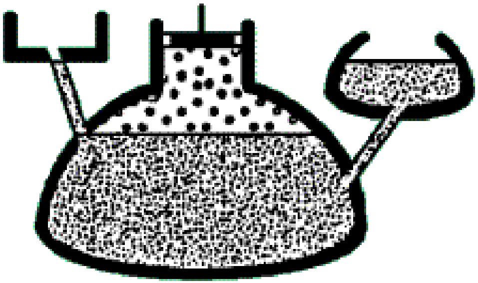
The proper dimensioning of an internal heating system seems to be more difficult because of the different currents due to pumping, agitation, thermo-convection and the inflow of bio-mass.

Under-floor heating systems have been very popular, as they have no disturbing parts in the digester itself. Due to sedimentation and the resulting worsening of heat transportation into the digester, under-floor heating is no longer recommended. With the growth of digester volumes and the need of bigger heating systems, it is also more difficult to build under-floor heating big enough to provide the necessary heat.

Heating coils installed at the inner wall of the digester are a rather new practice. Heating coils made out of steel are much more expensive than heating coils out of plastic material (PE). Materials developed during the last years make such a system more stable while not increasing the costs of the heating system.

Another option is to construct two digesters connected in series, the first heated, the second unheated. The first digester can be used as sedimentation tank , in which the substrate is heated up. The second digester is well isolated to reduce loss of heat.

Biogas



BIOGAS Digest

- Basics
- Framework Conditions
- Application and Product Development
- Costs and Benefits
- Program Implementation
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Biogas plants constitute a widely disseminated branch of technology that came into use more than 30 years ago in developing countries. There are hundreds of thousands of simple biogas plants now in operation, and each one of them helps to improve the living conditions of people in rural areas. Biogas systems are an efficient way of dealing with organic waste, dung and crop residues while making optimal use of their energetic as well as nutrient content.

In addition to generating renewable energy, biogas systems help to stimulate ecologically beneficial closed-loop systems in the agricultural sector while improving soil quality and promoting progress in animal husbandry and farming.

While the main focus is on biogas systems of simple design, the technology is nonetheless complex enough to warrant close attention to its proper application, planning and construction. Only a well-planned, carefully constructed and properly functioning biogas system will fulfill its purpose of improving living conditions in rural areas.

You will find useful and detailed information about all aspects of biogas plant design and maintainance, biogas appliances, social, political, economic and ecological framework conditions, planning and dissemination of biogas systems and last but not least country- and project-specific information.

Biogas Application

Piping Systems

The piping system connects the biogas plant with the gas appliances. It has to be safe, economic and should allow the required gas-flow for the specific gas appliance. Galvanized steel (G.I.) pipes or PVC-pipes are most commonly used for this purpose. Most prominently, the piping system has to be reliably gas-tight during the life-span of the biogas unit. In the past, faulty piping systems were the most frequent reason for gas losses in biogas units.

PVC piping

PVC pipes and fittings have a relatively low price and can be easily installed. They are available in different qualities with adhesive joints or screw couplings (pressure water pipes). PVC pipes are susceptible to UV radiation and can easily be damaged by playing children. Wherever possible, PVC pipes should be placed underground.

Final touches on a piping system with PVC pipes
Photo: Krmer (TBW)

Galvanized steel piping

Galvanized steel pipes are reliable and durable alternatives to PVC pipes. They can be disconnected and reused if necessary. They resist shocks and other mechanical impacts. However, galvanized steel pipes are costly and the installation is labor intensive, therefore they are only suitable for places where PVC is unavailable or should not be used.

Pipe diameters

The necessary pipe diameter depends on the required flow-rate of biogas through the pipe and the distance between biogas digester and gas appliances. Long distances and high flow-rates lead to a decrease of the gas pressure. The longer the distance and the higher the flow rate, the higher the pressure drops due to friction. Bends and fittings increase the pressure losses. G.1. pipes show higher pressure losses than PVC pipes. Table 1 gives some values for appropriate pipe diameters. Using these pipe diameters for the specified length and flow rate, the pressure losses will not exceed 5 mbar.

Table 1: Appropriate pipe diameter for different pipe lengths and flow-rate (maximum pressure loss < 5 mbar)

	Galvanized steel pipe	PVC pipe

Length [m]:	20	60	100	20	60	100
Flow-rate [m^3/h]						
0.1	1/2"	1/2"	1/2"	1/2"	1/2"	1/2"
0.2	1/2"	1/2"	1/2"	1/2"	1/2"	1/2"
0.3	1/2"	1/2"	1/2"	1/2"	1/2"	1/2"
0.4	1/2"	1/2"	1/2"	1/2"	1/2"	1/2"
0.5	1/2"	1/2"	3/4"	1/2"	1/2"	1/2"
1.0	3/4"	3/4"	3/4"	1/2"	3/4"	3/4"
1.5	3/4"	3/4"	1"	1/2"	3/4"	3/4"
2.0	3/4"	1"	1"	3/4"	3/4"	1"

The values in table 1 show that a pipe diameter of 3/4" is suitable for flow rates up to 1.5 m^3/h and distances up to 100 m (PVC pipe). Therefore one could select the diameter of 3/4" as single size for the hole piping system of small biogas plants. Another option is to select the diameter of l" for the main gas pipe and 1/2" for all distribution pipes to the gas appliances.

Lay-out of the piping system

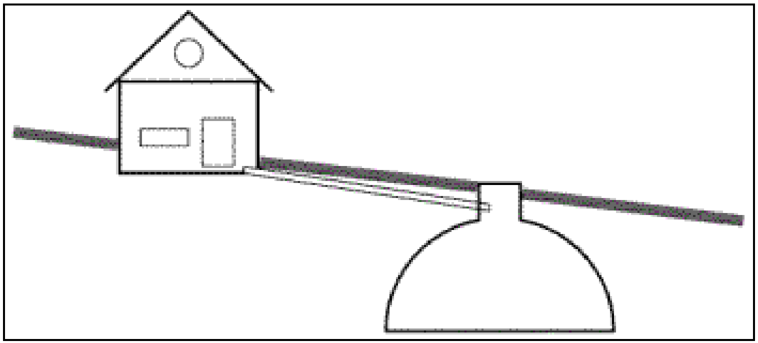
PVC can be used for all underground pipes or pipes that are protected against sun light and out of the reach of children. For all parts of the piping system that are above ground one should install galvanized steel pipes. Therefore it is recommended to use l" G.I. steel pipes for the visible part of the piping system around the biogas digester. For the main pipe one uses l" PVC pipe placed underground. The distribution pipes should be 1/2" G.I. steel pipes or PVC pipes, depending whether they are installed above or under the wall plastering. But even though G.I. pipes are less susceptible to damage, placing them underground should always be the preferred solution.

PVC pipes have to be laid at least 25 cm deep underground. They should be placed in a sand bed and be covered with sand or fine earth. One should carefully back-fill the ditches in order to avoid stones lying directly above the pipe.

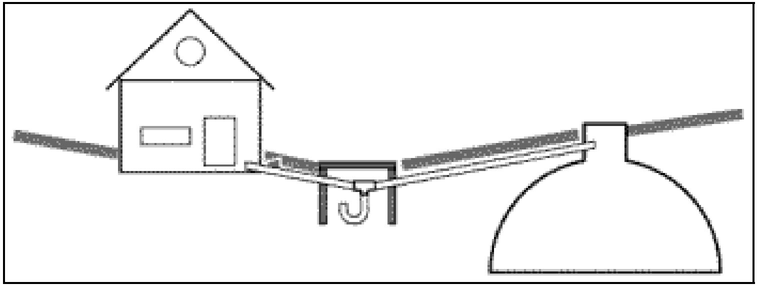
When the piping is installed - and before refilling the ditches - it has to be tested for possible gas leakage. This can be done by pumping air into the closed piping system up to a pressure that is 2.5 times the maximum gas pressure of the biogas plant. If pressure loss occurs within few hours, every joint of the piping system has to be checked with soap water. Soap-bubbles indicate any leakage of gas.

Water traps

Due to temperature changes, the moisture-saturated biogas will form inevitably condensation water in the piping system. Ideally, the piping system should be laid out in a way that allows a free flow of condensation water back into the digester. If depressions in the piping system can not be avoided, one or several water traps have to be installed at the lowest point of the depressions. Inclination should not be less than 1%.

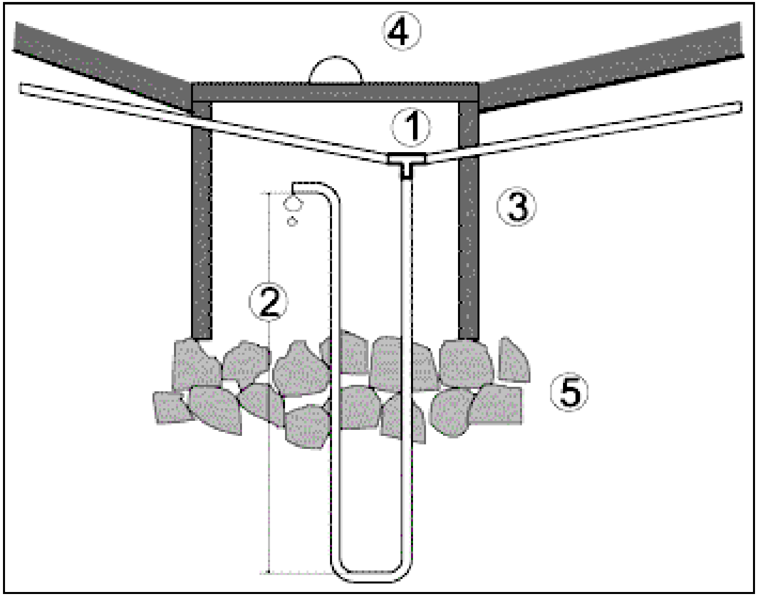


Piping system with straight slope from kitchen to digester. No water trap required as condensation water drains into the digester
Source: TBW



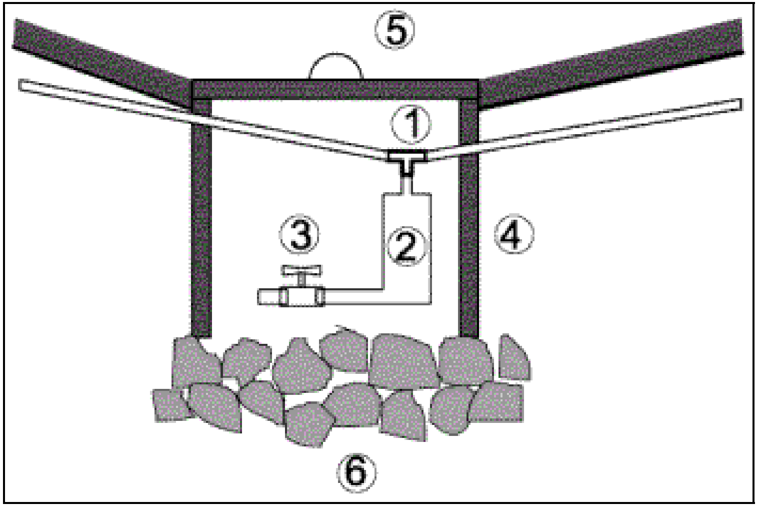
Wherever condensation water cannot drain back into the digester, a water trap becomes necessary
Source: TBW

Often, water traps cannot be avoided. One has to decide then, if an 'automatic' trap or a manually operated trap is more suitable. Automatic traps have the advantage that emptying - which is easily forgotten - is not necessary. But if they dry up or blow empty, they may cause heavy and extended gas losses. In addition, they are not easily understood. Manual traps are simple and easy to understand, but if they are not emptied regularly, the accumulated condensation water will eventually block the piping system. Both kinds of traps have to be installed in a solid chamber, covered by a lid to prevent an eventual filling up by soil.



Automatic water trap: (1) T-joint in

the piping system, (2) water column, equal to max. gas pressure + 30% security, (3) solid brick or concrete casing, (4) concrete lid, (5) drainage
Source: TBW



Manual water trap: (1) T-joint, (2) buffer storage for condensated

water, (3) manual tap, (4) casing, (5) concrete lid, (6) drainage
Source: TBW

Valves

To the extent possible, ball valves or cock valves suitable for gas installations should be used as shutoff and isolating elements. The most reliable valves are chrome-plated ball valves. Gate valves of the type normally used for water pipes are not suitable. Any water valves exceptionally used must first be checked for gas-tightness. They have to be greased regularly. A U-tube pressure gauge is quick and easy to make and can normally be expected to meet the requirements of a biogas plant.

The main gas valve has to be installed close to the biogas digester. Sealed T-joints should be connected before and after the main valve. With these T-joints it is possible to test the digester and the piping system separately for their gas-tightness. Ball valves as shutoff devices should be installed at all gas appliances. With shutoff valves, cleaning and maintenance work can be carried out without closing the main gas valve.

Biogas
Application

Plasters and Coats for Digester and Gas-Holder

In industrialized countries, most of the new digesters are built of gas-tight concrete or steel.

Additives are mixed into the concrete to render it gas-tight. If existing concrete vessels are used, their gas-tightness has to be checked. Often, they have not been built from gas-tight concrete or cracks have formed over time which allow the gas to escape.

It is important to check the digester and piping system for gas-tightness prior to putting the biogas unit in service. If leakage is detected only during operation, the digester has to be emptied, cleaned and plastered again. Rectifying a leakage before the initial filling is a lot cheaper.

In developing countries, digesters are usually masonry structures. The plastering has to be watertight up to the

Inside plaster of the gastight section of a fixed dome digester
Photo: Kellner (TBW)

lowest slurry level and gas-tight from the lowest gas level upwards (gas-holder). The plaster has to resist moisture and temperatures up to 60C reliably. The plaster must be resistant to organic acid, ammonia and hydrogen sulfide. The undercoat must be absolutely clean and dry.

Cement plaster with special additives

Good results in water- and gas-tightness have been achieved by adding 'water-proofer' to the cement plaster. For gas-tightness, double the amount of water-proofer is required as compared to the amount necessary for water-tightness. The time between the applications of the layers of plaster should not exceed one day, as the plaster becomes water-tight after one day and the new plaster cannot adhere to the old plaster. The following 'recipe' from Tanzania guarantees gas-tightness, provided the masonry structure has no cracks:

1. layer: cement-water brushing;
2. layer: 1 cm cement : sand plaster 1 : 2.5;
3. layer: cement-water brushing;
4. layer: cement : lime : sand plaster 1 : 0.25 : 2.5;
5. layer: cement-water brushing with water-proofer;

6. layer: cement : lime : sand plaster with water proofer and fine, sieved sand 1 : 0.25 : 2.5;
7. layer: cement screed (cement-water paste) with water-proofer.

The seven courses of plaster should be applied within 24 hours.

A disadvantage of cement plaster is their inability to bridge small cracks in the masonry structure as, for example, bituminous coats can do.

Bitumen (several layers)

Bitumen coats can be applied easily and remain elastic over long periods of time. Problems arise in the application as the solvents are inflammable (danger of explosion inside the digester) and a health hazard. Bitumen coats cannot be applied on wet surfaces. The drying of masonry structures requires several weeks, unless some heating device (e.g. a charcoal stove) is placed inside the digester for two to three days. Furthermore, the bituminous coat can be damaged by the up-and-down movement of the slurry.

Bitumen coat with aluminum foil

On the first still sticky bitumen coat, aluminum foil is mounted with generous overlaps. A second layer of bitumen is applied on the aluminum foil. Gas-tightness is usually higher compared to the several layers of bitumen without foil.

Water-thinnable dispersion paint

These paints are free from fire- or health hazards. Most of them, however are not gas-tight and not resistant to moisture. Only those dispersion paints should be used which are explicitly recommended for underwater use and which form a gas-tight film.

Single- and dual component synthetic resin paints

Synthetic resin paints form elastic, gas-tight coats which can resist rather high physical load. They are comparably expensive, their use seems only justified if the coating has to resist mechanical stress. This is usually the case with fixed dome plants. Measurements have given evidence that the masonry structure of a fixed dome stretches, though minimally, after filling and under gas pressure.

Paraffin

Paraffin, diluted with new engine oil, is warmed up to 100 -150C and applied on the plaster which has been heated up with a flame-thrower. The paraffin enters into the plaster and effects a 'deep-sealing'. If paraffin is not available, simple candles can be melted and diluted with engine oil.

Biogas
Application

Pumps for Biogas Plants

Pumps are required to bridge differences in height between the levels of slurry-flow through the biogas unit. They can also be required to mix the substrate or to speed up slow flowing substrates. If substrates have a high solids content and do not flow at all, but cannot be diluted, pumps or transport belts are essential.

Pumps are driven by engines, are exposed to wear and tear and can be damaged. They are costly, consume energy and can disrupt the filling process. For these reasons, pumps should be avoided where possible and methods of dilution and use of the natural gradient be utilized instead.

If pumps cannot be avoided, they can be installed in two ways:

- Dry installation: the pump is connected in line with the pipe. The substrate flows freely up to the pump and is accelerated while passing through the pump.
- Wet installation: the pump is installed with an electric engine inside the substrate. The electric engine is sealed in a watertight container. Alternatively, the pump in the substrate is driven by a shaft, the engine is outside the substrate.

Types of pumps

Rotary pumps

Rotary pumps operate with a rotor which presses the liquid against the outside wall of the rotor chamber. Due to the geometry of the chamber the liquid is pushed into the outlet pipe. Rotary pumps are very common in liquid manure technology. They are simple and robust and used mainly for substrates of less than 8% solids content. The quantity conveyed per time unit depends largely on the height of lift or the conveying pressure. The maximum conveying pressure is between 0,8 and 3.5 bar. The quantity that can be conveyed varies from 2 to 6 m^3per min. at a power input of 3 - 15 kW. Rotary pumps cannot, usually, be used as a sucking device. As a special form of rotary pumps, the chopper pump deserves mentioning. It's rotor is equipped with blades to chop substrates with long fibers like straw and other fodder parts before pumping them up. Both wet and dry installation is possible with rotary pumps.

Positive displacement pumps

Positive displacement pumps are normally used for substrates with higher solids content. They pump and suck at the same time. Their potential quantity conveyed is less dependent on the conveying pressure than with rotary pumps. The direction of pumping / sucking can be changed into the opposite direction by changing the sense of rotation. In biogas units, mainly the eccentric spiral pump and the rotary piston pump (both positive displacement pumps) are used. For better access, a dry installation is the preferred option.

Eccentric spiral pump

This pump has a stainless steel rotor, similar to a cork screw, which turns in an elastic casing. Eccentric spiral pumps can suck from a depth of up to 8.5m and can produce a pressure of up to 24 bar. The are, however, more susceptible to obstructive, alien elements than rotary pumps. Of disadvantage is further the danger of fibrous material wrapping round the spiral.

Rotary piston pump

Rotary piston pumps operate on counter-rotating winged pistons in an oval casing. They can pump and suck as well and achieve pressures of up to 10 bar. The potential quantity conveyed ranges from 0.5 to 4 m^3/min. The allow for larger alien objects and more fibrous material than eccentric spiral pumps.

Table 1: Types of pumps in comparison

	rotary pumps	chopper pumps	eccentric spiral pump	rotary piston pump
solids content	< 8 %	< 8 %	< 15 %	< 15 %
energy input	3 - 15 kW	3 - 15 kW	3 - 22 kW	3 - 20 kW
quantity conveyed	2 - 6 m^3/min	2 - 6 m^3/min	0,3 - 3,5 m^3/min	0,5 - 4 m^3/min
pressure	0,8 - 3,5 bar	0,8 - 3,5 bar	< 25 bar	< 10 bar
structure of substrate	medium long fibers	long fibers	short fibers	medium long fibers
max. size				

of obstructive elements	approx. 5 cm	depending on choppers	approx. 4 cm	approx. 6 cm
intake	**not** sucking	**not** sucking	sucking	sucking
suitability	suitable for large quantities; simple and robust built	suitable for long-fiber substrates which need to be chopped up.	Suitable for high pressures, but susceptible to obstructive bodies	higher pressures than rotary pumps, but higher wear and tear
price comparison	cheaper than positive displacement pumps	depending on choppers	similar to rotary piston pump	similar to eccentric spiral pump

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Biogas
Application

Slurry-Use Equipment

For the use of biogas slurry, a multitude of tools and technologies have been developed. They differ mainly according to the quantities of digested material. Big differences exist as well between developing and industrialized countries, depending on the technological development and the cost of labor. Slurry use technologies range from hand-application with the help of a bucket to mechanized distribution, supported by GPS (global positioning system) and a computer on board of the liquid manure spreader. The choice of technology essentially depends on the amount of slurry and the area to be fertilized as well as on the financial means and the opportunity cost of labor.

On ***small farms in developing countries***, simple but effective tools are used. They include buckets, scoops, containers with straps, wooden wheelbarrows with lids, barrels on wheels and others. These tools allow a precise application of slurry. The most economic way to apply slurry is by means of gravity, either by a network of small slurry furrows or by mixing slurry in the irrigation system. Both options require a gradient of at least 1% (for irrigation water) and 2% (for slurry distribution), sloping from the biogas plant's overflow point to the fields.

Making best and least labor-intensive use of the slurry is an important planning parameter. Especially where gravity distribution is feasible, the positioning of the biogas plant and the expansion chamber and the level of the expansion chamber overflow are of high importance. In rather flat areas, it should be considered to raise both the stable and the biogas-plant in order to allow a slurry distribution by gravity.

Device for slurry distribution by tractor.

Photo: Krmer (TBW)

In ***industrialized countries*** and for ***large plants in developing countries*** two methods of mechanized distribution systems have evolved:

1. **Distribution via piping systems**

   The slurry is pumped directly from the slurry storage tank onto the field and is distributed there. If the pump is rather small and the pressure and transported amounts are low, the distribution can be done by hand. With increasing pressure and transported amounts, the distribution system is attached to a tractor. The tractor does not have to be very powerful as there is no need to pull a heavy tanker. The main advantage of this method is the low ground pressure and the ability to enter into fields of steep slope, of fragile soil structure and during bad weather.

   The biogas slurry, if it is not too viscous, can be applied with a liquid manure rainer. The disadvantages are the costly pump and the expensive piping system. Therefore, this method is only economic for fields close to the slurry storage container.

2. **Distribution via tanker**

   The tanker is filled at the slurry storage and pulled to the field for distribution. Below are the principal distribution systems ex-tanker:

With reflection plate

The slurry is squirted through a nozzle against a reflection plate which, by it's special form, diverts and broadens the squirt. An improvement of the simple reflection-plate-distribution is a swiveling plate which leads to a more even distribution.

Direct application through sliding hoses

The slurry is pumped into a distribution system which feeds a number of hoses which move closely to the ground. The slurry is applied directly on the soil surface, therefore reducing nutrient losses. Distances between the hoses can be adjusted to suit different plant cultures.

Hoses with drill coulters

The soil is opened with two disks (drill coulters) in a v-shape. The slurry is applied with sliding hoses into the v-furrows, which are closed behind the hose. This application method could be labeled 'sub-surface application'. It is the most advanced in terms of avoiding nutrient losses. Similar to the hose application, distances between application rows are adjustable. Alternatively to the hose application, the slurry can be positioned by a metal injector.

The application methods close to the soil surface, in contrast to the broadcasting methods, have the advantage of a higher degree of exactness and less nutrient losses to the atmosphere. Fertilization can be better adjusted to plant needs. In contrast to broadcast-spraying, direct application is possible even at later stages of plant growth without damaging the leaves. Disadvantages are the rather sophisticated machinery necessary and the high costs involved. Direct application methods are, therefore, mostly used as inter-farm operation.

Separation of slurry and drying of the moist sludge

In industrialized countries, the slurry is usually separated by means of separators and sieves. The water is re-fed into the digestion process or distributed as liquid manure while the moist sludge is dried or composted. As a simple technology for separation, slow sand-filters can be used.

The moist sludge can be heaped on drying beds, filled in flat pits or simply placed on paved surfaces near the biogas plant for drying. Depending on climatic conditions, large drying areas may be necessary. Drying times and nutrient losses can be reduced by mixing dry substances with the moist sludge. A disadvantage of all drying methods, again depending on the climate, is the high loss of nutrients. In particular heavy rains can wash out the soluble nutrients. Losses of nitrogen, for example, can amount to 50% of the overall nitrogen and up to 90% of the mineral nitrogen. Drying of the moist sludge can only be recommended where long distances and difficult terrain hampers transport to the fields or if composting is difficult for lack of manpower and lack of dry biomass.

Composting of slurry

Dry plant material is heaped in rows and the liquid slurry is poured over the rows. Ideally, plant material and slurry are mixed. The mixing ration depends on the dry matter content of plant material and slurry. The main advantage is the low nutrient loss. Compost, containing plant nutrients in a mainly biologically fixed form, is a fertilizer with long-term effects. It's value for improving soil structure is an additional positive effect of importance.

distributed organizations, to supercomputers, to a small home server, if it's Linux, we know it.)

Biogas
Application

Underground Water

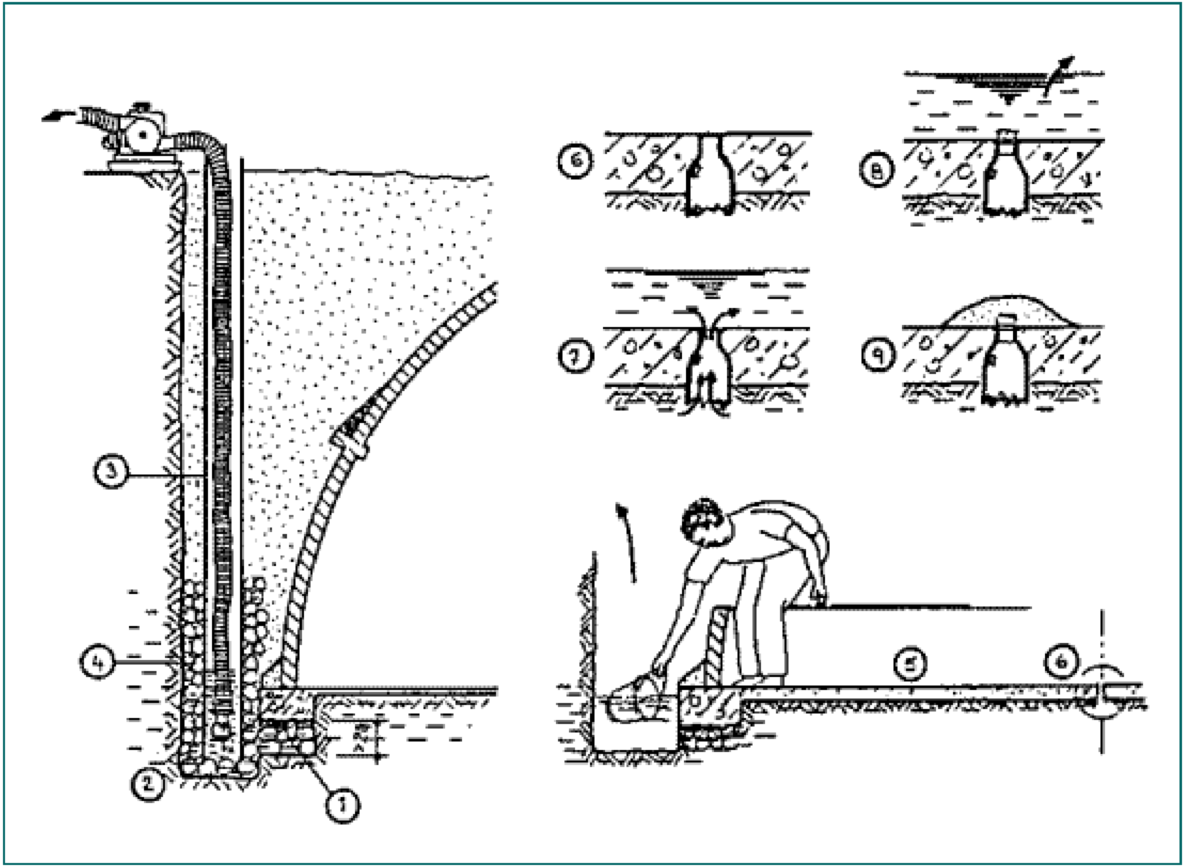
Underground water features in all three steps of biogas implementation:

- During planning, the site selection and design of the digester can eliminate most of the problems caused by groundwater and threats to groundwater.
- During construction, groundwater can be a nuisance, effecting additional costs. But it is during construction, that serious leakage can be avoided.

- During operation, little can be done but to monitor the quality of water and to avoid surface spilling.

By positioning the biogas plant and the well, a great deal of drinking water safety can be achieved. First, the distance should be at least 30 m, second, the biogas plant should be downstream of surface- and groundwater flows and third, the well should be above the biogas unit to avoid contamination through surface spilling.

During construction, ground water must be drained. An empty biogas digester can develop such buoyancy, if surrounded by water, that the whole shell is lifted. The figure below illustrates some simple techniques how to deal with ground water during construction of small biogas plants.



Dealing with ground water during construction: The foundation rests on a stone packing (1) to drain the water

into the pump-sink (2). A layer of gravel prevents blockage of the drain. A vertical pipe (3) allows pumping even when back-filling has be done. The lower part of the pipe is surrounded by a stone packing (4). If the ground water is only slightly higher than the digester bottom or if no pump is available, the construction must be flooded. The floor must be of solid concrete (5). Water must be kept away until the outer wall has reached above the ground water table and has been plastered from the outside. Several bottles without bottoms are placed into the concrete (6). When scooping of water has stopped, ground water passes through the bottle and floods the floor (7). After completing the masonry work and covering the dome with soil, the bottle is closed and water might be taken off the digester bottom (8). The cap of the bottle is covered with cement mortar (9). In case of high ground water table a conical or bowl-shaped solid concrete slab is required.

Source: Sasse, Kellner, Kimaro: Improved Biogas Units for Developing Countries, GATE 1991

During the operation of the biogas plant further attention has to be paid to keeping the groundwater clean. Seeping biogas digesters and unprotected slurry storage can pollute water sources chemically (nitrate poisoning can be fatal for infants) and biologically (mainly with toilet biogas plants). Reasons may be wrong configuration of security devices like the pressure relief valves or because of leakage in lower parts of the digester. Smaller cracks, however, close up in the course of time through particles in the slurry.

Trace metals applied to natural systems do not pose a threat to groundwater quality because trace metals are usually removed from the percolating water by adsorption or chemical precipitation within the first few meters of soil, even in rapid infiltration systems with high hydraulic-loading rates.

Bacterial removal from effluents passing through fine soils is quite complete. It may be less complete in the coarse, sandy soil used for rapid infiltration systems. Fractured rock or limestone cavities may provide a passage for bacteria that can travel several hundred meters from the point of application. This danger can be avoided by proper geological investigations during site selection.