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Aidewise-biogas plant for biogas production

The Aidewise-biogas plant (ABP) is an advanced version of small-scale biogas plants that are constructed in China and in India for many years, considering the experiences gained in Germany with new large-scale plants. The ABP is proposed by Dipl-Ing. Angelika Steinhauser (Aidewise GmbH, Domdidier / Switzerland) and Prof. Dr.-Ing. Dieter Deublein (University of Applied Sciences, Munich / Germany), both authors of the book: biogas from waste and renewable resources, Wiley-publishing comp., 2nd Edition, 2010.

The ABP is described in details below. The instructions and the associated calculations/hints are provided for free to the market. The developers do not guarantee that a plant built according to these instructions meets all expectations. The developers would be grateful about feedback regarding experiences in building and operating the Aidewise-biogas plant (prof.deublein@aidewise.com)

The ABP offers following advantages to private homes, public buildings such as schools, etc. and small settlements:

- Supply of energy in the form of combustible gas to be used for cooking, lighting, electricity
- Higher gas yield in comparison to other systems due to the more effective plug flow in the ABP.
- Possible fermentation of sewage sludge, manure etc. and agricultural wastes (not wood).
- Rare cleaning of the reactor.
- Possible residue use as fertilizer in gardens and fields. Advantage of reduced irrigation with river water or well water. Nutrient-poor soils experienced a significant improvement.
- Simple and safe design layout.
- Easy expansion possible, if needed, for example because the owners have created more animals or could increase crop yields by using the residue of the plant.

Table 1: Comparison of biogas plants, which are nowadays available on the market.
1 Aidewise-biogas plant, 2 fixed dome plant, 3 floating cup plant, 4 plug flow plant, 5 UASB, 6 El Jicaro, 7 steel tank (+ = good, + / - = under circumstances good - not good)

	1	**2**	**3**	**4**	**5**	**6**	**7**
Investment costs in Euro (estimation)	**800**	1500	1800	200	3000	5000	15000
Gas tightness of the gasholder	**+**	+/-	+	+	+/-	+/-	+
Fluid leakage possibility of the container	**+/-**	+/-	+/-	+	+/-	+/-	+
Easy construction by untrained persons	**+**	+	+	+	+/-	-	-
Easy to be operated	**+**	+	+	+	+	+	-
No danger of break down	**+**	+	+	+	+	-	+
Constant temperature	**+**	+	+/-	+	-	-	-
Good ventilation for safe access	**+**	-	+	-	+	-	+
Accessibility of material to be purchased locally	**+**	+	+	-	+/-	-	-
Durability of the reactor in years	**20-30**	20 - 30	20 - 30	2 - 5	10 - 20	20 - 30	10-15
Durability of the gasholder in years	**5**	20 - 30	5	2 - 5	10 - 20	10	10 - 15
Suitable for animal wastes	**+**	+	+	+	+	+	+
Suitable for vegetable waste	**+**	-	-	-	-	-	+
Constant gas pressure	**+**	-	+	+	-	+	-
Gas cleaning (drying)	**-**	-	-	-	-	-	-
No continuity of supply required	**+**	+	+	+	-	+	+
Stirring of the scum possible	**+**	-	+	-	-	-	+/-
Sludge easily to be removed	**+**	-	-	-	-	-	+
Material not valuable to be stolen	**+**	+	-	+	+	-	+

1. Basic considerations to the plant size

1.1. Availability of biomass

The yield of the ABP depends on the amount of waste materials and therefore on the number of animals, that are available. It is recommended to oversize the plant.

Please keep following in mind:

- Each cow produces on average 10 kg dung per day and 1 kg of fresh manure. This results in a biogas volume of 0.5 m³ per day per cow. With 8 cows it sums up to 88 kg manure/dung and 4 m³ biogas per day.
- Each pig produces on average 1 kg manure and dung per day. This results in a biogas volume of 0.06 m³ daily. With 10 pigs 10 kg pig manure/dung and hence 0.6 m³ of biogas are produced.
- Each adult person produces an average of 1 kg faeces/urine per day (24 h), which results in 0.06 m³. 6 people give a total of 6 kg of waste and 0.36 m³ biogas.
- Corn straw contains appr. 62 % organic dry matter and can be fermented to appr. 0.3 m³ biogas.

1.2. Demand for gas

The size of the biogas plant needs to meet the energy requirements of the users. Gas is required

- for cooking (three times daily) and gas lighting 0.5 m³ biogas per person are required.
- for running a power generator. An engine requires 0.5 m³ biogas per hour and per horse power.

The size needs to be adjusted accordingly.

1.3. Size of the biogas plant

For the calculation of the size of the plant a mixing ratio biomass : water of 1:0,5 is choosen. A residence time of 60 days is assumed, taking in consideration that bio waste needs more time to degrade.

While designing the ABP, a possible increase in the number of animals and silting of the reactor should be considered. Therefore, the plant should be designed rather too large than too small.

Theoretically the minimum reactor size can be calculated taking in consideration the number of people, cows and pigs.

Table 2: Size of the reactor depending on the available feed deriving from the number of people, cows and pigs

People	4 - 8	4 - 8	4 - 8	4 - 8	4 - 8	4 - 8	4 - 8	4 - 8	4 - 8	4 - 8
Cows	2	4	6	2	2	4	4	4	6	8
Pigs	0	0	0	2	4	2	4	6	4	8
Volume of the reactor	3	5	7	3	3	5	5	6	7	10
Proposed length of the reactor	3	5	7	4	4	5	6	6	8	10
Biogas per day in m³	1.3	2.3	3.6	1.42	1.54	2.42	3.14	2.66	3.54	4.78

1.3.1. Typical farmer´s family with cows and pigs

A farmer´s family, consisting of 6 grown up persons owning 8 cows and 6 pigs produces waste material, which can be converted to biogas, as follows

- 6 kg of faeces/urine
- 88 kg cattle manure/dung
- 8 kg pig manure/dung

Operating the ABP with this feed and a mixing ratio biomass : water of 1 : 0,5 a water inlet of 51 kg is required, which results in an overall inlet into the reactor of 153 kg per day. At a residence time of 60 days the total amount adds up to 9180 kg. Assuming a density of 1000 kg/m³ of the feed the minimum required volume of the bioreactor is 9.2 m³.

The plant delivers 4.8 m³ biogas per day.

1.3.2. School (100 children, 5 teachers), 1 couple (caretaker) with 2 cows and 3 pigs

- 100 Pupils (1/2 of the amount of faeces of an adult) produce on average (6 school days per week (7 days), 8 hours per day(24 h)) 100 x ½ x 6/7 x 8/24 = 14 kg faeces/urine per day
  5 teachers produce on average (6 school days per week),
  8 hours per day) 5 x 6 d/7 d x 8 h/24 h = 1.4 kg faeces/urine per day
  2 caretaker produce on average (7 days per week, 24 hours per day)
  2 kg faeces/urine per day
  In total 14 kg + 1.4 kg + 2 kg = 17.4 kg faeces/urine
- 22 kg cattle manure/dung
- 3 kg pig manure/dung

The total feed to the plant including mixing water is 63.6 kg per day. At a residence time of 60 days the total amount adds up to 3816 kg. Assuming a density of 1000 kg/m³ of the feed the minimum required volume of the bioreactor is 3.9 m³.

1.4. Installation site

The installation site should have the following features

- Sunny place sheltered from the wind – orientation so that the sun shines to the front side
- Source of water in 10 minutes walking distance away.
- Kitchen as close as possible.
- Minimum 10 meters from the drinking water well
- Space nearby for composting of the residue
- Place, where the earth is removable

2. Construction manual for a 10 m³ ABP

For further considerations the size of the bioreactor is assumed to be 10 m³.

Note that the length unit used here is centimeter. It is important that the dimensions in centimeters are reached. The below given number of bricks is only an example.

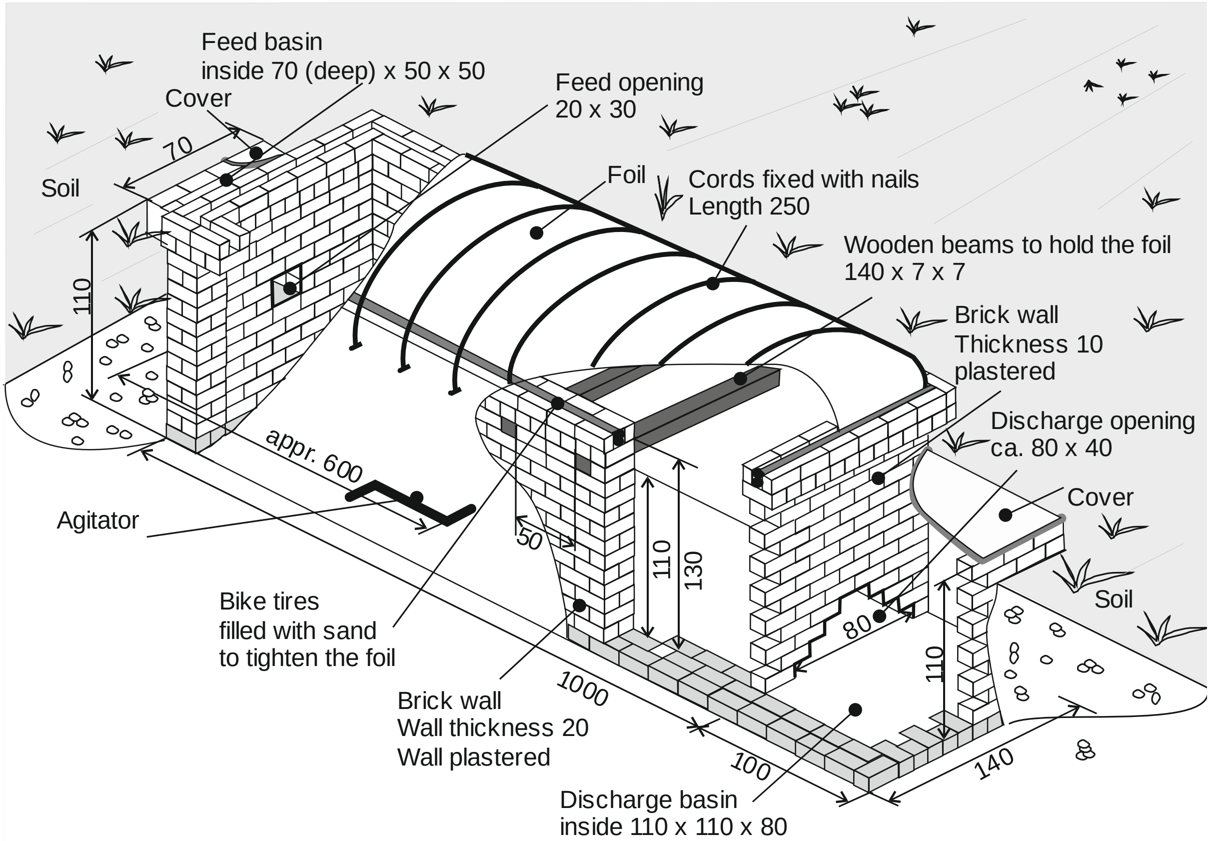

Fig. 1: Aidewise-biogas plant

2.1. Procedure

Note here that mortar for walls should be mixed in the ratio 1:4 (cement / sand) and mortar for plastering in the ratio 1:3 (cement / sand).

1. Reactor and discharge basin: dig a hole, about 1 m deep, 1.4 m wide and 11 m long (according to the length of the reactor) and a ramp on one side.
2. Feed basin: dig at one front edge (feed) a platform, 0,6 m deep, 0.7 m wide and 0.6 m long.
3. Put a 3 cm thick sand layer onto the floor in 1 m depth and onto the platform.

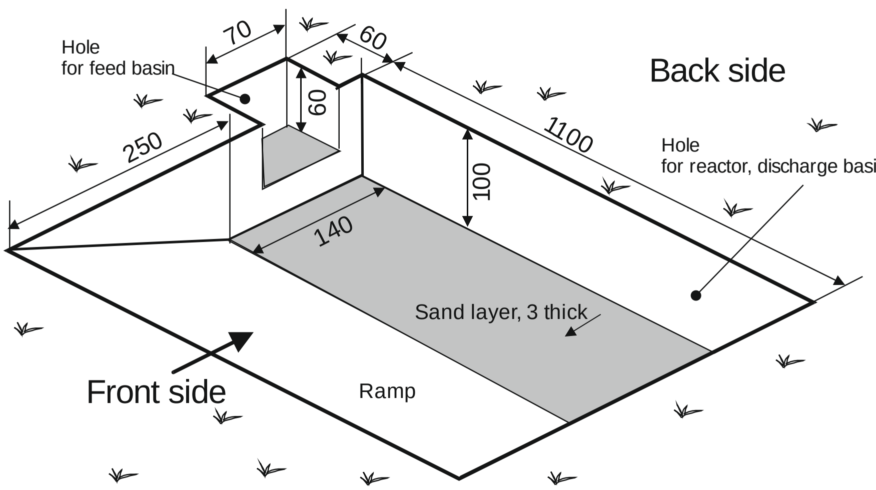

Fig. 2: Step 1–3: dimensions of the hole to be digged

4. Reactor and discharge basin: lay bricks onto the sand layer in 1 m depth 1.4 m wide and 11 m long, 7 cm high (1 brick-stone layer, 530 stones).
5. Reactor and discharge basin: brick walls around the floor to approximately 0.5 m height (5 layers of bricks, note that at the front side the wall consists of two brick-stones side by side per layer, 700 stones)
6. Feed basin: lay bricks on the platform (height 7 cm) 0.6 m wide and 0.6 m long (20 stones).
7. Where the agitator shaft is planned to be embedded, put 5 stones one on each other and brick on top two stones cross (10 stones) (see Fig. 3). Lay in the agitator, constructed acc. to Fig. 3.

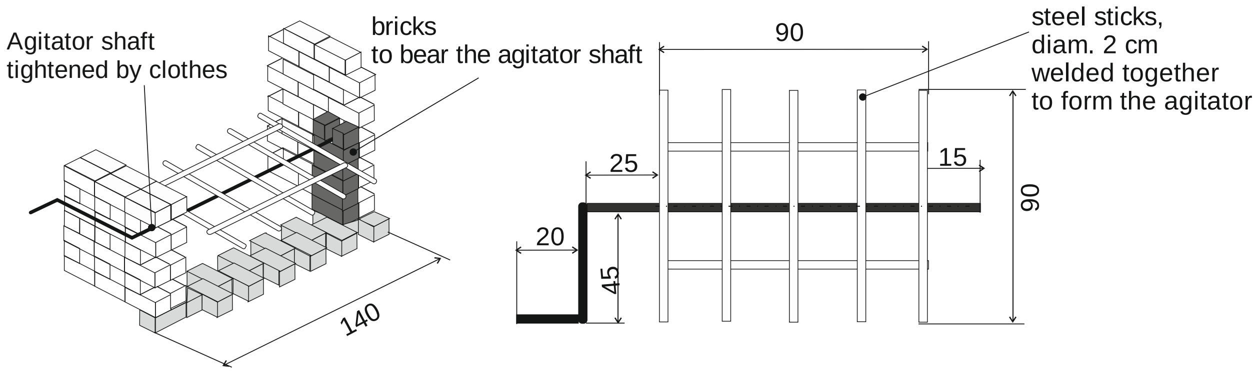

Fig. 3: Step 7: How to install the agitator (left), dimensions of the agitator (right)

8. Brick all walls, including the intermediate walls between feed and discharge basin to approximately 1.1 m (7 layers of bricks, at front side two bricks side by side, 1050 stones).
9. Seal the agitator shaft well, e.g. by clothes, which are stuffed around the agitator shaft in the hole.
10. Plaster the inner wall of the reactor.
11. Fill the gap between the wall and the surrounding soil by mud and compress it carefully.
12. Lay 18 wooden beams (preferably 7 x 7 cm, 140 cm long) at a distance of about 0.5 m from each other over the walls. The wooden beams shall bear the foil, when it sinks down due to low biogas pressure.
13. Add a layer of bricks to the side wall filling the gap between the wooden beams (1 layer of bricks, 115 stones).
14. Close to the kitchen fix a piece of PVC pipe (diameter 1,5 cm) in the wall of the reactor as gas outlet and tighten it with a cloth.
15. Brick a brick row around the reactor (200 Stones). The bricks have to be laid crossways to the wall below (see Fig. 4).
16. Brick 2 brick rows (180 stones) each standing vertically on the long side around the reactor wall, so that a mould is formed between the bricks (see Fig. 4). Now the reactor walls reach abt. 50 cm above soil, the walls around feed and discharge basin 20 cm above soil.

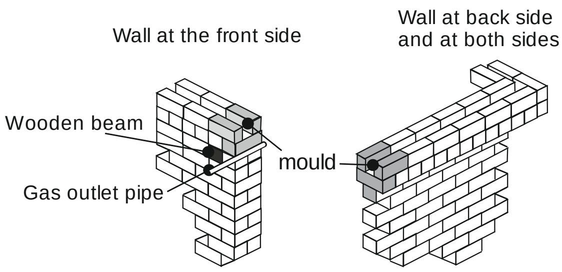

Fig. 4: Step 13 – 16: How to form the mould and to fix the gas outlet

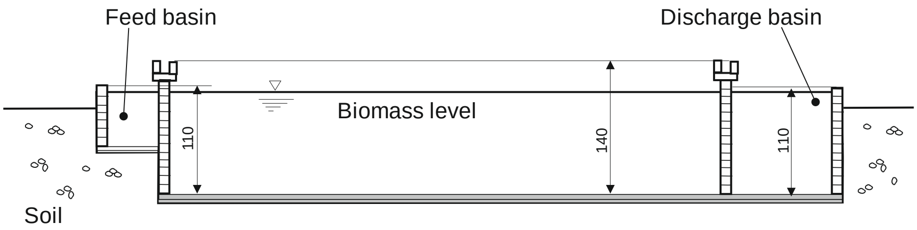

Fig 5: Cross sectional drawing of the reactor

17. Cut a foil (1.5 mm thick, HDPE) to the size 3 m x 12 m
18. Fold the foil to a cover

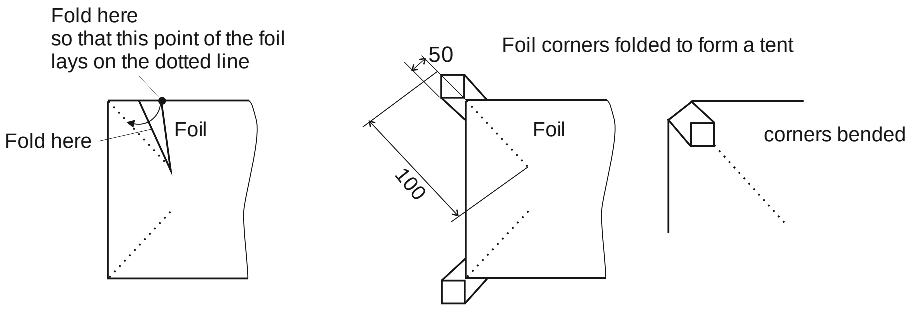

Fig. 6: Step 18: How to fold the foil

19. Pull the foil over the reactor
20. Put the edges of the foil into the mould between the bricks
21. Lay 22 about 2 m long bike tires filled with sand into the mould on the foil
22. Fill the mould with sludge
23. Cut 40 cords to 2.5 m length. Lay them at a distance of approximately 0.25 m from each other over the reactor. Fix the cords at both ends with nails tightened to the reactor wall. Instead of cords also a wire frame can be fixed above the plastic foil like a roof.
24. Cover the bioreactor with a roof - e.g. a corrugated plate -to protect the foil from direct sunlight.
25. Cover the inlet and outlet basin with a shelf in order to prevent rain water ingress. The shelf must be loaded with a stone so that it cannot be removed easily.
26. Fill a plastic vessel with iron nails and pass the biogas through to capture hydrogen sulfite.
27. Connect the PVC pipe socket in the foil to the plastic vessel and the vessel to the kitchen using 10 mm PVC pipes. In this pipe branches and connections are to be avoided as far as possible for tightness reasons. All pipe connections must be sealed with plastic tape. The pipe should be sloped downwards so that condensate can be withdrawn.

2.2. Material required for a 10 m³ Aidewise-biogas plant

- abt. 3065 bricks (240 x 115 x 71 mm)
- 50 bags (50 kg) sand
- 15 bags (50 kg) cement, preferable water-tight
- 18 wooden beams (in cross section approximately 7 x 7 cm, 1.4 m long) – the beams can also be strong round branches.
- 1 agitator as to be seen in the drawing constructed from 7 steel sticks 90 cm long, 1 steel stick 130 long, 1 steel stick 45 long and 1 steel stick 20 long, all steel sticks of 2 cm diameter.
- 1 foil (1.5 mm thick, HDPE) 3 x 12 m
- 1 PVC pipe 1,5 cm (30 cm long) and enough 1,5 cm pipes for the connection to the kitchen
- 22 bicycle tires (2 m)
- 40 cords, 2.5 m long
- Plastic vessel containing abt. 100 rusted iron nails

3. Starting and operating of the 10 m³ ABA

1. Mix cow dung with water in a 1:2 ratio and fill the mixture into the bioreactor. Cow dung has proved to be optimal for fermentation. It should be used as substrate to boot the system, since it is not prone to acidification.

   If waste water is used for dilution, then the risk of over-acidification arises. If a small piece of dolomite or lime is added, less acid is created, but ammonia. Therefore it is better to reduce the amount of waste water and dilute the dung with fresh water until the plant runs stable.

   After some days the bioreactor produces biogas. The biomass flows through the reactor. The residue can be removed from the discharge basin.

2. Scoop the residue out of the discharge basin with a bucket. In order to remove the sludge the use of a bucket is recommended, which sinks to the ground of the basin.

   If a green mass is coming out of the reactor, it is overloaded. Then recirculate a part of residue to get higher biogas yield.

3. Feed daily 5 buckets (10 liters each) into the inlet basin, so that a biomass : water ratio of 1:0,5 is achieved. But before, take off residue.

4. Rotate the agitator every day about 30 times slowly, so that the scum breaks and the sludge is conveyed to the outlet basin.

   If the foil is bulging between the cords a too high pressure may be created. Release some biogas to the environment by opening the PVC pipe to the kitschen.

5. Put a weight (stone) on the foil, when the gas pressure drops while cooking in the kitchen.

   If the gas smells the rusted nails must be exchanged. The nails can be regenerated by keeping them at open air, so that the sulfur reacts. The regeneration is possible only three times. Then the nails must be replaced by other rusted nails.

6. The bioreactor has to be cleaned from time to time, perhaps one time a year. To do so remove the bike tires from the mould. Pull off the foil partly. Remove the biomass. Now, enter the bioreactor and clean it. On such occasions, inspect and repair the plaster on the wall. Then again seal the foil carefully.

   Attention !

   Never touch the inner surface of the reactor with a sharp object.

4. Use of biogas

It is recommended to clean the gas first, by passing through an iron filing (rusty nails) to remove the H2S. A lime bath can be used to remove the CO2, if desired.

Kitchenware requires the following gas in l / h as follows:

Gas stove with 2” – 6 “ burner	280 - 550
Mantle lamp	80 - 160
Refrigerator 18” x 18” x 12”	78

Operating a motor for power generation or as an engine

Each engine must be adjusted to the special features of gas from a biogas plant. For a gasoline engine a 5 mm hole has to be drilled in the gasoline line in front of the carburator, and a pipe has to be connected to the biogas reactor with a control valve. The engine must be started with gasoline. Then it can be switched to biogas. Gas diesel engines can be converted to biogas when the air intake is connected to the gas hose. It is recommend to readjust the ignition.

Operation of a biogas stove

Because biogas has a low pressure, a special burner has to be constructed for cooking. The gas pipe to the burner must be enlarged to 15 mm. The gas supply is throttled by a perforated metal plate (1.5 - 2 mm diameter). An efficient burner consists of a tin can filled with stones as weights. The box has 6 holes (1.5 mm diameter) on the top. The gas flows into the box from the bottom through a pipe (2 mm diameter).

When the air supply is reduced in accordance with the quantity of gas, the flame is hotter.

Lighting

Methane gives a soft white light, when it is burned in a fiery mantle. The light is not quite as bright and shiny as a kerosene lantern.

Use of organic solid as fertilizer

By anaerobic digestion of biomass the residue is better in its quality compared to the residue obtained from fresh or composted dung. The liquid effluent contains many elements that are essential for plants: nitrogen, phosphorus, potassium, small amounts of metallic salts.

The residue can be applied in liquid or sun-dried form. Although about 90% of all pathogens originate from feces, the residue is nearly germ-free through the anaerobic treatment. The quality of the residue can be further increased by composting (5 weeks) before using it as fertilizer.

5. Trouble Shooting

The Aidewise-biogas plant is nearly maintenance free and has a lifespan of about 25 years.

Observation	Possible reason	Recommendation
No gas	Insufficient inoculum	Wait longer
	Too cold	Warm up the water added to the reactor
		Install a tent to prevent heat losses to the surrounding air
	Not sufficient biomass	Increase biomass supply
	Leak in the foil or in the piping	Put water to the foil and try to find the hole, where gas bubbles can be noticed
	Scum	Agitate more intensively
Leakage from the stones	Failure of construction	Remove foil, empty the reactor to that level, stop leakage by closing the hole
Gas stove not working	gas supply blocked by condensate	Clean
	Too little pressure	Put a weight to the foil
	Gas pipe leaking	Check gas pipe
The gas does not contain enough methane	Biomass does not have its correct consistency	Wait
	too much excess air	Throttle air supply at the stove
		Eliminate air leaks at the stove
		Increase the diameter of the gas pipe to 15 mm to prevent a too high pressure drop in the gas pipe
Flame dies	Too little pressure	Put a weight to the foil
	Gas can escape, e.g. over water trap	Control