Recommendation for fire brigade response when at risk through biogas plants

Short title: biogas plants
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Change history:

Version: 3 (March 2021)
Replaces: Version 2 (September 2014)
First version: July 2012

Significant changes:
- Editorial changes

Note:

A spelling that is equally fair to all genders is desirable. However, since corresponding newer spellings generally lead to major restrictions in readability, this has been dispensed with. Thus, for the entire document, the masculine form includes all genders, unless explicitly stated otherwise.

Table of Contents

1. Aim of the Instruction Sheet

As fire brigade operations in biogas plants always include aspects of NBC operations in accordance with FwDV 500, the special operating instructions for such operational situations are shown, which are intended to prevent personal injury and damage to property.

2. General Information

Biogas plants are used to produce combustible gas by fermenting biomass from agriculture (e.g. slurry, solid manure), households or industry (e.g. material from organic waste bins, slaughterhouse waste, biomass from food production and industrial residues, etc.).
Gas production is based on the natural decomposition process of organic substances in oxygen-free systems, known as fermentation, which mainly produces methane and carbon dioxide.
In most biogas plants, the resulting gas is utilised on site in a combined heat and power plant (CHP) to generate electricity and heat. There are also plants that feed the biogas produced into the natural gas grid after it has been purified and compressed. Biogas plants are operated on the one hand as agricultural plants, but also exist in industrial form and at sewage treatment plants.
A fertiliser known as digestate is produced as a by-product of biogas production. Source: *[http://de.wikipedia.org/wiki/Biogasanlage]*

3. Structure and function of a biogas plant

Due to the different hazards that can occur in a biogas plant at the scene of an emergency, the main parts of the plant are briefly described here.

In agricultural biogas plants, slurry is produced by the animals in the barn and collected in a preliminary pit. Further substrates are delivered to the reception area and fed into the digester together with the liquid manure. In the digester, the starting materials are then fermented into biogas, which is collected in the film storage tank.
The fermentation residue is pumped into a storage tank and from there it is spread on the fields.
The biogas is converted into electricity and heat in the combined heat and power plant (CHP).

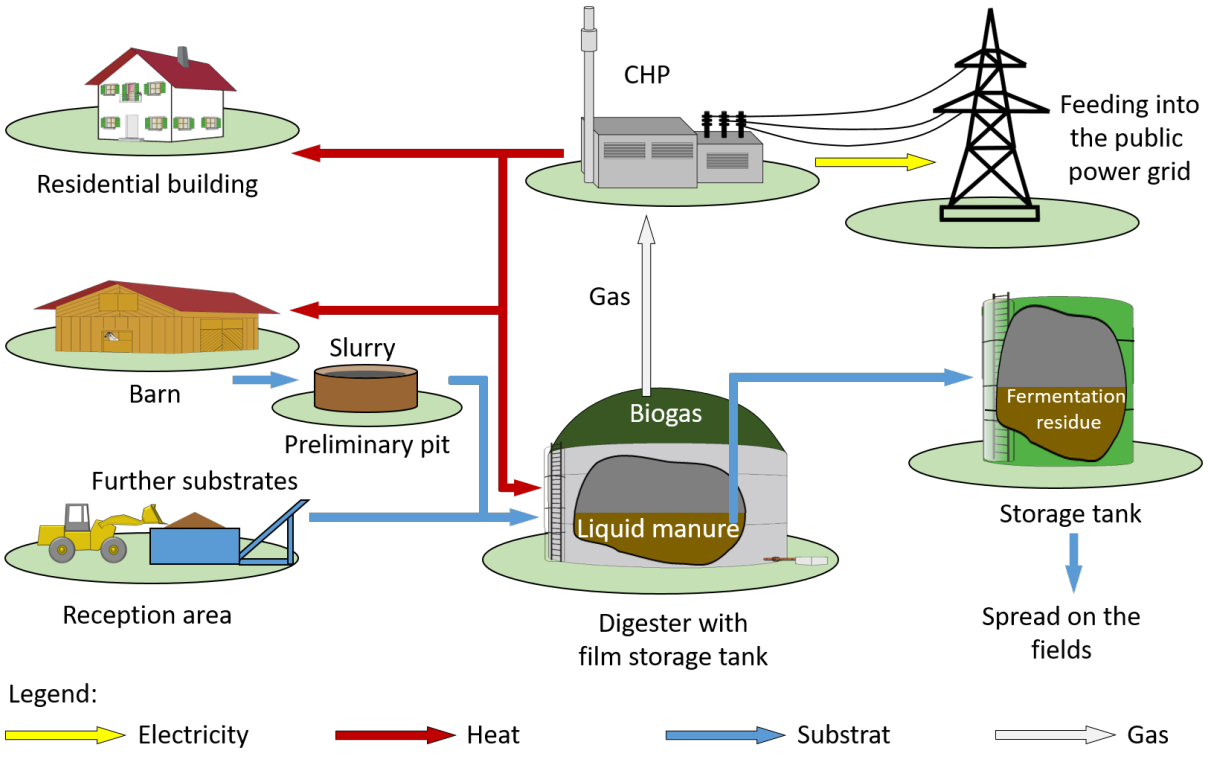

Figure 1: Schematic structure of a biogas plant [source: vfdb-Ref.10]

Digester

The centrepiece of a biogas plant is the fermenter, in which the biogas is produced from the mixture fed in during a digestion period lasting several weeks. The mixture is constantly circulated at elevated temperatures.

The biogas produced in the digester is then stored temporarily in a biogas storage tank in order to compensate for fluctuations between gas production and gas consumption. The gas is stored either in the digester itself under a foil cover or in a separate gas storage tank.

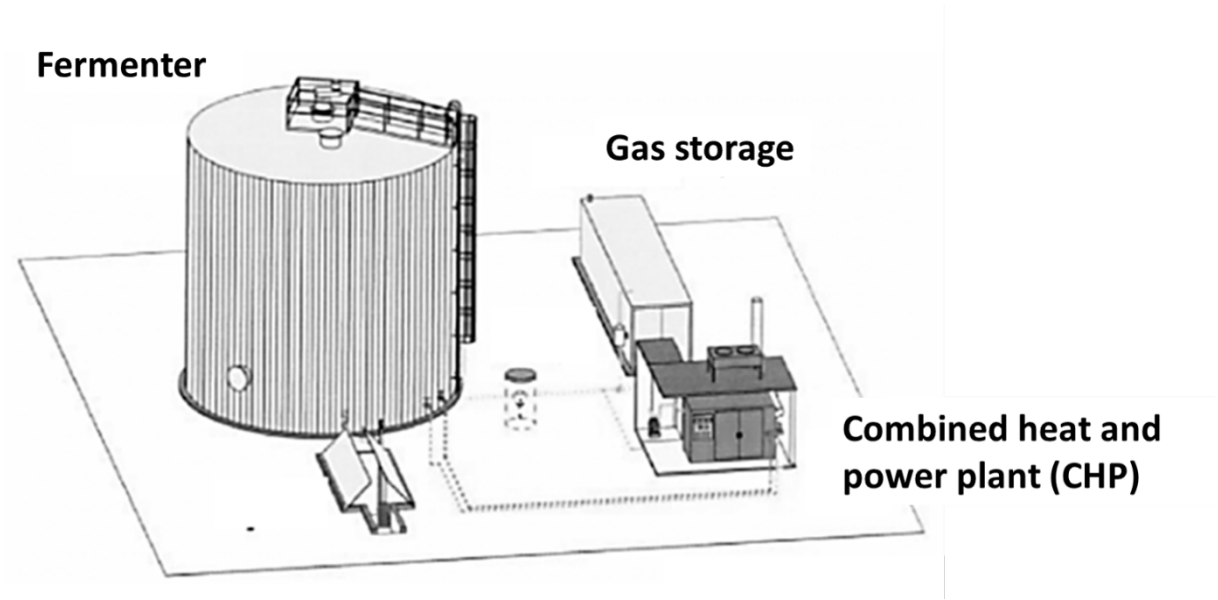

Figure 2: Schematic representation of gas generation [Source SMUL Sachsen]

Attention:

Before driving into the fermenter, switch off the agitator and secure it against restarting (if necessary, place a safety guard at the control unit)!

Figure 3: Fermenter [Source: Uni Köln]

Gas storage
Fixed above-ground, underground and buried gas storage tanks, as well as flexible balloon, cushion and foil storage tanks above slurry stores and fermenters are used for gas storage. Balloon and cushion storage tanks are set up in installation rooms, which must be sufficiently cross-ventilated.

Attention:

In the event of damage, only enter rooms with fermenters or gas storage tanks with self-contained breathing apparatus and body protection!
Ex measuring devices must be used when entering the operating area!

Pay particular attention to explosion protection during ventilation!

Only use explosion-protected devices in hazardous areas!

Figure 4: Gas storage with foil memory [Source: Agrotel]

Combined heat and power plant
An emergency stop switch for the CHP unit and a shut-off valve for the gas supply are usually provided outside the installation room.
Large quantities of ignition oil (e.g. heating oil, diesel oil, biodiesel) can be stored in the installation room (max. 50 kW electrical output). Very hot surface temperatures (up to 750 °C) and corresponding electrical hazards are to be expected.

Figure 5: Example of a combined heat and power plant [Source: Biogas-Nord/ENSPAR Biogas]

Gas-carrying pipes
Gas pipes are laid between the fermenter, gas storage tank and combined heat and power plant. Inside buildings, gas-carrying pipes are generally made of metal. Outside buildings, plastic pipes are also used.

4. Composition and properties of biogas

Biogas essentially consists of methane (40 - 75 % by volume) and carbon dioxide (25 - 55 % by volume). In addition to these two substances, hydrogen sulphide (0.01 - 2.0% by volume), ammonia, hydrogen, water vapour and nitrogen are also present.
The exact composition varies and depends on the general conditions during biogas production. In particular, the content of hydrogen sulphide (H2S) is highly dependent on the fermentation substrates used and the quality of the fermentation (high H2S contents are possible, especially when fermenting meat, food waste and highly fluctuating quality).
The density of biogas is similar to that of air, so the mixture is neither significantly lighter nor significantly heavier than air.
In biogas plants, it is usually stored at almost zero pressure (< 0.1 bar).

Table 1: Composition of biogas [Source: Biohandbuch Bayern und http://www.biogas-netzeinspeisung.at]

Compo-nent	Methane (CH_4)	Carbon dioxide (CO_2)	Water (H_2O)	Nitrogen (N_2)	Hydrogen (H_2)	Oxygen (O_2)	Hydrogen sulphide (H_2S)	Ammonia (NH_3)
Share of biogas [%]	**40 - 75**	**25 - 55**	**0 - 10**	**0 - 5**	**0 - 1**	**0 - 2**	**0 - 2**	**0 - 1**

Attention:

Biogas contains C hazardous substances such as methane, carbon dioxide and hydrogen sulphide.

Methane is highly flammable, explosion hazard

Hydrogen sulphide is toxic and flammable

Self-contained breathing apparatus required

5. Special hazards during firefighting operations in biogas plants

Due to the composition of NBC hazardous substances in biogas described above, the following special hazards must be observed in the area of biogas plants.

- Respiratory poisons
- Fire hazard
- Explosion hazard
- Electricity
- Risk of burns on the supply lines

5.1. Danger from respiratory toxins

Methane is non-toxic, but ingestion of methane can lead to increased respiratory rate (hyperventilation) and increased heart rate, it can cause short-term low blood pressure, numbness in the extremities, drowsiness, mental confusion and memory loss, all caused by lack of oxygen.

Hydrogen sulphide is a foul-smelling, colourless, highly toxic gas that is flammable and slightly soluble in water. Due to its high density, the gas collects on the ground and in pits and shafts.
Hydrogen sulphide has the ability to anaesthetise the odour receptors, which means that higher concentrations can no longer be detected by smell.
The threshold value for anaesthetising the odour receptors is a concentration of 100 ppm H_2S or

more.

The following physiological effects occur in humans:

- ~100 ppm: Irritation of the mucous membranes of the eye and respiratory tract, salivation, coughing irritation, anaesthesia of the olfactory receptors
- > 200 ppm: headache, breathing difficulties
- > 300 ppm: nausea
- ≈ 500 ppm: weakness, drowsiness, dizziness
- > 500 ppm: convulsions, unconsciousness

Long-term exposure to low doses can lead to fatigue, loss of appetite, headaches, irritability, poor memory and lack of concentration.

In humans, life-threatening symptoms of poisoning occur depending on the concentration:

- < 100 ppm: after several hours
- > 100 ppm: < 1 hour
- ~ 500 ppm: fatal in 30 minutes
- ~ 1,000 ppm: fatal in a few minutes
- ~ 5,000 ppm: fatal in a few seconds

This means that H2S concentrations of 0.1% by volume (1000 ppm) are fatal after a few minutes and those of 0.5% by volume (5000 ppm) after a few seconds. Unconsciousness occurs within one or more breaths at such concentrations.

The high proportion of **carbon dioxide** in biogas leads to asphyxiation in lower lying areas.

Respiratory toxins (CH_4, H_2S, CO_2, NH_3, etc.) may escape from the reception area, the fermentation residue tank and during substrate feeding (pre-pit, hydrolysis, hygienisation, mixing tank, etc.). The formation and release of these substances are influenced by the chemical and physical conditions in the substrate. When mixing substances with different pH values or when mixing already fermented material with warmer substrates, H_2S, CO_2 and NH_3 can be produced suddenly.

5.2. Danger due to fire/explosion

Biogas is usually stored under foil covers. Tests have shown that there is no acute risk of explosion if the foil burns through as long as the gas burns off completely at the leak or as long as the escaping gas is flared. It only occurs if the gas escapes in an uncontrolled manner and is ignited by an ignition source.
The areas in which explosive gas-air mixtures are to be expected during normal operation of a system (Ex zones) are labelled with a sign. Furthermore, an Ex zone plan and an explosion protection document must be available at the system.

The safety-related key figures are as follows:
At a volume fraction of between 4.4 and 16.5 per cent in the air, methane forms explosive mixtures or hazardous explosive atmospheres. These explosion limit values apply under normal air conditions. At higher CO2 concentrations (e.g. in a biogas plant), the explosion range becomes smaller.
Methane is highly flammable, the ignition temperature is 600°C.

Hydrogen sulphide forms highly flammable gas-air mixtures. The explosion range is between 4.3% by volume as the lower explosion limit (LEL) and 45.5% by volume as the upper explosion limit (UEL).
For systems that accept solids (especially substrates from food production such as milk powder, etc.), there may also be a risk of dust explosions in the delivery and handling area.

5.3. Electricity

Electricity hazards are possible in the area of the CHP unit or the feed-in to the public power grid. The power is fed into the low-voltage or high-voltage grid (up to 30 kV - observe minimum distances in accordance with DIN VDE 0132 when discharging!)

5.4. Risk of burns

There is a risk of burns on the CHP unit, on the supply lines to the heat storage tank and on the heat storage tank itself. If the pipe breaks, there is a risk of scalding from escaping hot water and/or water vapour.

5.5. Further hazards associated with biogas upgrading and grid feed-in systems

For biogas plants that do not utilise the raw biogas produced in a CHP unit but feed it into the natural gas grid, it is generally necessary to treat the raw biogas.
In particular, CO2, moisture and interfering foreign gases (H2S, NH3, etc.) must be extracted from the raw biogas by means of appropriate chemical-physical process steps. Such plants are comparable to industrial chemical plants and - depending on the process - have corresponding chemical and physical hazards due to the plant technology and auxiliary materials used.

Natural gas compressors are also required to feed the gas into the grid, and odorisation using mostly toxic and flammable additives (tetrahydrothiophene / THT, tert-butyl mercaptan / TBM or acrylic acid methyl ester) is usually necessary.

6. Measures

Due to the involvement of NBC hazardous substances in accidents in biogas plants, Fire Service Regulation 500 "Units in NBC Operations" (FwDV 500) must be applied.

6.1. General measures

General principles of use according to FwDV 500:

Observe wind direction (approach, course of operation)
Keep your distance
Pay attention to personal protection (breathing poisons, explosion hazard)
Cordon off the danger zone immediately
Self-contained breathing apparatus (SCBA), body protection
Avoid ignition sources
Test tube (H2S) / measuring device (H2S sensor) / carry out Ex measurements
Be sure to observe further spread

General tactical instructions for carrying out operations
Implementation of deployment

- When approaching, pay attention to the wind direction and approach with the wind if possible. Also be careful when approaching, do not get out of the vehicle without respiratory protection. Avoid ground depressions.
- Keep your distance, preferably over 50 m, as high H2S concentrations may be possible. Position the vehicle outside the hazardous area and below the ETW of H2S (ETW-4: 20 ppm).
- Only deploy essential personnel in the danger zone.
- Always wear suitable self-contained breathing apparatus.
- Clear the immediate danger zone outdoors and cordon off a large area depending on the ETW determined.
- Permanent Ex measurements
- Multi-gas measuring devices and test tube measurements
- Avoid ignition sources

- Use explosion-protected devices and non-sparking tools
- Involve specialised personnel / operating personnel

Attention!

Maintain a sufficient safety distance!

Wear self-contained breathing apparatus in the danger zone!

Pay attention to wind direction!

Check and observe the Ex area (CH_4, H_2S)

Special tactical instructions

6.2. Rescue of people without fire

- Approach with the wind if possible
- Position the vehicle outside the danger zone due to the risk of explosion and respiratory poisons, note the change in wind direction.
- Rescue people under respiratory protection
- Ensure fire protection

6.3. Biogas leakage without fire

In principle, the same points apply as listed under 6.1!

A few points should be noted in particular:
- If possible, consult the operator of the system. Observe fire brigade plan.
- Large-scale cordoning off may be necessary - check ETW (H2S)
- Permanently, extensively and comprehensively monitor explosion hazards - especially in sinks!
- Ensure fire protection
- Shut down the system with the help of the operator if possible.
- Actuate emergency stop
- Shut off gas supply
- Call in specialised personnel

Note: Biogas production cannot be switched off immediately. Even if refilling is stopped immediately, biogas will continue to be produced for several days. Overpressure and leakage of biogas and/or fermentation gas may occur. In consultation with the operator, the CHP unit and the flare can continue to be operated if necessary.

Environmental hazard due to substrate leakage
- Utilise the collection volume of the system for liquid manure, consult the operator
- Collecting / diking substrate
- Prevent discharge into open waters

6.4. Biogas leakage with fire

In principle, the same points apply as listed under 6.1 and 6.2!

A few points should be noted in particular:
- Actuate safety devices (emergency stop, gas valve)
- Secure openings to other buildings
- Allow burning gas pipes to burn
- Observe safety distances for electrical installations

Fire at the fermenter or gas pipework system
Do not extinguish until the gas supply has been shut off
- Allow residual gas to burn off in a controlled manner
- Protect surroundings
- Be aware of dangers due to formation of toxic gases in fire smoke (e.g. SO_2, white colour of smoke)

Fire at/in the CHP unit or gas treatment plant
- Shut off the gas lines and activate the emergency stop
- Prepare triple extinguishing attack (foam (escape of ignition oil), powder, CO_2)
- Observe safety distances for electrical systems in accordance with DIN VDE 0132, especially when using foam
- Consult operational documents for special hazards and C-hazardous substances as well as other emergency instructions

Fire in the switch cabinet room, low-voltage distribution board or transformer
Shut off gas lines and activate emergency stop
Switch off the power
Extinguish preferably with CO2 / distances and extinguishing agents according to DIN VDE 0132

Fire on building parts or insulation
- Extinguish with water, foam and/or CO2.
- Protect system components, especially gas storage facilities, from heat radiation, flying sparks and flying sparks.
- Secure openings to other parts of the building.

7. Preparation for deployment

Operational documents
The following documents may be available:
- Operating instructions prepared by the operator of the system
- Explosion protection document in accordance with the Ordinance on Industrial Safety and Health (in particular overview of the Ex zones)
- "**Fire brigade plans for buildings**" in accordance with DIN 14095, drawn up by the operator in consultation with the fire brigade
- **Operational plans** with alarm and response organisation, prepared by the fire brigade, which should generally provide the following information:
    - Approach, escape routes, extinguishing water extraction, extinguishing water retention, collection containers for liquid manure
    - Specialist advisors, experts, authorities, TUIS
    - Hazard areas with hazard groups based on site and floor plans
    - Hospitals, specialised clinics, emergency services, medical specialists
    - Companies with specialised equipment such as suction or tanker trucks
    - Reserve forces and supplies of material and catering

8. Literature references

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