Co-funded by the Erasmus+ Programme of the European Union

Project-N° 2019-1-CZ01-KA202-061409

LEARNING SCENARIO	BIOGAS
MODULE 3	HEALTH AND SAFETY

COLOPHON

Authors

This module is part of the Learning Scenario *Biogas*. It is developed in the frame of the European project “BioComp”.
The authors are Jens Hofmann and Marek Botek.

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PREFACE

The learning scenario Biogas has been developed as part of the Erasmus+ project BioComp. In that project, the most relevant competences for professions in the sector BBE are analysed, described and ranked. See https://navigator.biocompetences.eu/. Based on these competences this learning scenario has been developed for EQF-level 3-4. The focus is on technical competences.

Nr	Competences, ranked according importance	Modules
B1	Management - Identifying needs and mechanisms of the overall management of the biogas production process.	1, 2
B2	Operate biogas plant - Operate equipment, which treats energy crops and waste from farms, called anaerobic digesters. Ensure the equipment functions correctly in the transformation of biomass to biogas, which is used for the generation of heat and electricity.	1
B3	Resolve equipment malfunctions - Identify, report and repair equipment damage and malfunctions; communicate with field representatives and manufacturers to obtain repair and replacement components.	4
B4	Composting of organic waste (Biomass) - Identifying needs and technological responses: to know the types of bio-waste, the recovery routes (composting, digestion, incineration).	5
B5	Recycling - Identifying needs and technological responses - To know the circular economy, compost processing and the use of fermentation.	1, 3
B6	Composting of organic waste (Biomass) - Identifying needs and technological responses: to know the chemistry and biological processes of composting.	1, 5
B7	Bioconversion process - Identifying needs and technological responses - To assess needs and to identify, evaluate, and control the heating process of biological material, control the combustion process, know and be able to analyse the chemical, thermal, and biochemical methods.	3, 5
B8	Composting of organic waste and management - Identifying needs and technological responses - To assess needs and to identify, evaluate, and control the heating process of biological material, control the combustion process, know and be able to analyse the chemical, thermal, and biochemical methods.	5

These 8 most relevant competences are covered by the following 6 modules:

1. Circular economy
2. Introduction
3. **Health and Safety**
4. Maintenance
5. Malfunctions
6. Composting and disposal

Apart from these 6 text documents, the scenario also has a trailer and a WIKI with background information. To support the teacher, didactic guidance is available. It can be used for all scenarios and also includes suggestions for learning activities to develop personal and transversal competences. For this guidance, see the *Pedagogical Guidelines* in the Navigator.

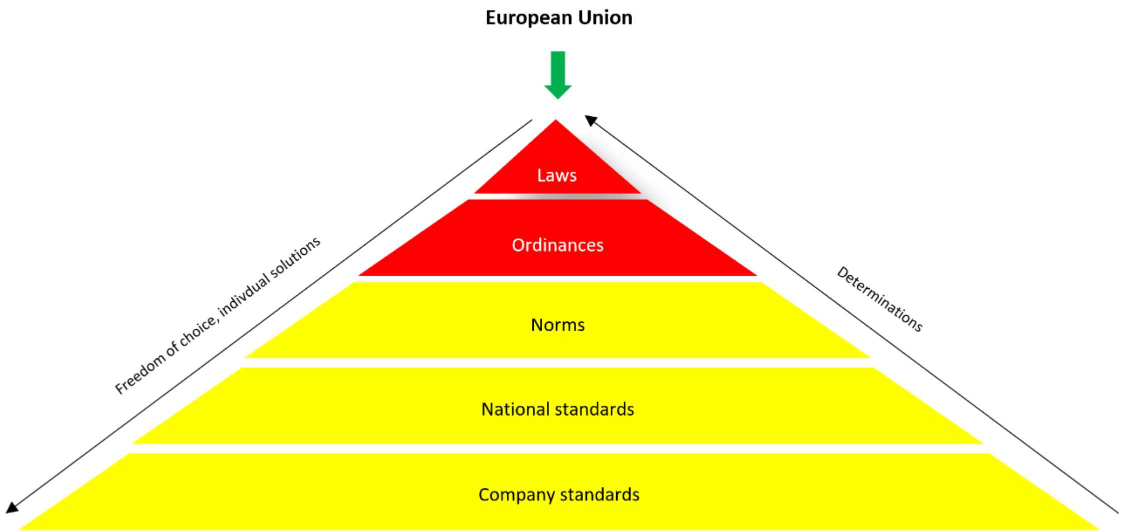
CONTENT

Module 3 contains the following topics:

1. Introduction to the module

The operation of a biogas plant requires compliance with occupational health and safety ("H&S") to prevent accidents at work. It includes a bundle of measures, means, and methods to protect employees from work-related health and safety hazards. They are derived from a hierarchy of norms (**pyramid of norms**).

Picture 1. Pyramid of norms



Workplace safety is regulated by Directive 1999/92/EC and Directive 2009/104/EC. Every member state of the EU must specify technical rules to implement these directives into their national laws. Subsequently, the situation in Germany and the Czech Republic is briefly presented.

In Germany, the Federal Ministry of Labour and Social Affairs is responsible for regulation of industrial safety and health. The Federal Institute for Occupational Safety and Health (BAuA) as a federal authority belongs to the Federal Ministry of Labour and Social Affairs (BMAS) and as a major governmental research institution advises the Federal Ministry of Labour and Social Affairs in all matters of safety and health and of the humane design of working conditions. This institute is responsible for these technical regulations for safety in the workplace.

In the Czech Republic, there exists a non-binding good practice guide for implementation of Directive 1999/92/EC.

Wherever possible, the employer should prevent the formation of an explosive atmosphere. To meet this highest priority requirement, as defined in Article 3 of Directive 1999/92 / EC, the first step in assessing the risk of an explosion is to determine whether a hazardous explosive atmosphere can be created under the given conditions. It must then be determined whether it can be ignited.

The evaluation process must be repeated for each work or production process and for each operational state and change of state in the technology. The assessment of new or existing operations should be based on the following operating conditions:

- normal operating conditions, including maintenance;
- commissioning and decommissioning;
- failure, anticipated failure conditions;
- misuse that can reasonably be expected.

The explosion hazard assessment must be complete. Important factors are:

- used work equipment;
- building structures and arrangements;
- substances used; working and technological conditions;
- their possible interaction and reaction with the work environment.

Appropriate methods for assessing the risk of an explosion associated with working procedures or technology are those that lead to a systematic approach to technology control and process safety.

IMPORTANT: During operation of a biogas plant, the "TOP" principle is applied to ensure H&S measures.

T – Technical measures, such as fall protection, **cordon off danger spots.**

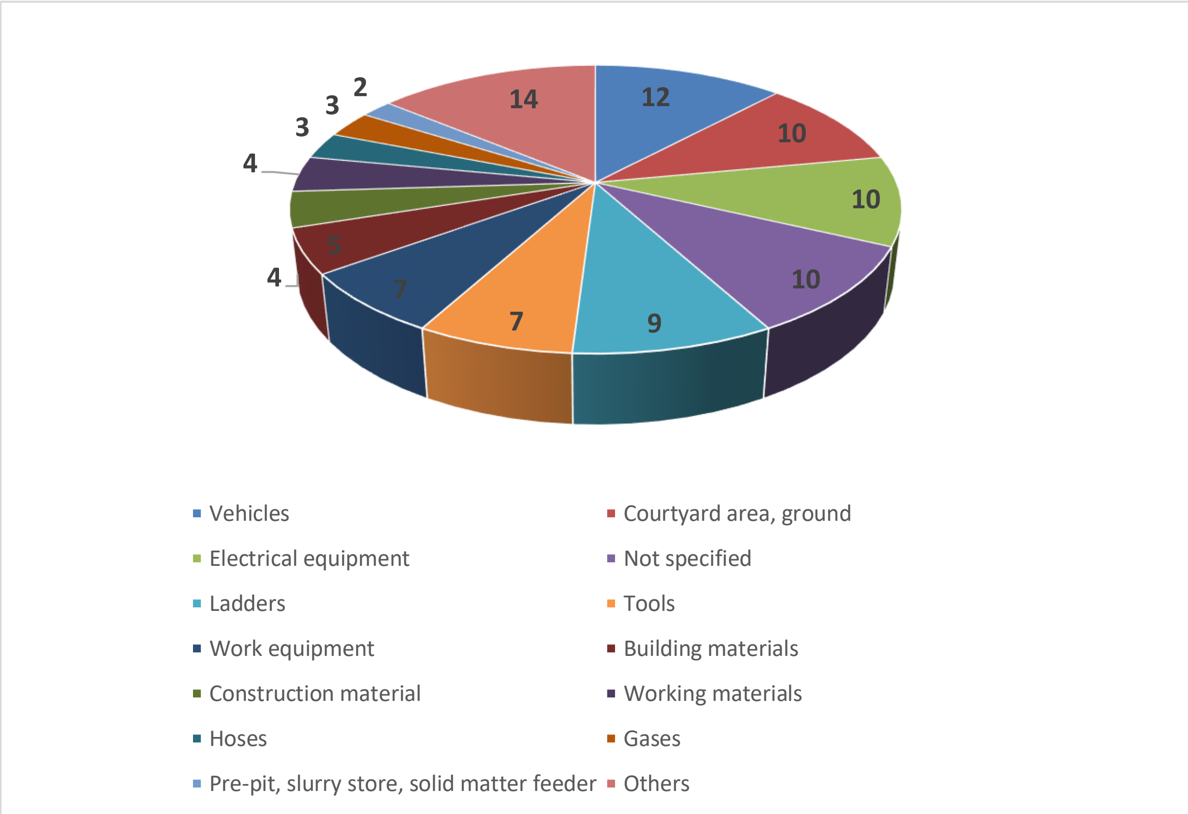
O – Organisational measures, such as **Visual inspection of work equipment before it is used.**

P – Person-related measures, such as PSA (personal protective equipment, safety briefings).

2. Frequency of work accidents and dangers

The frequency of work accidents translates into preventive measures for workers of a biogas plant. Most reported accidents are in the fields of electrical equipment, on the ground, and with vehicles. A lower percentage of accidents are in the fields of working equipment, building and construction materials, and with gases.

Picture 2: Biogas plant: Frequency of work accidents in % (2011-2015, Germany)



Possible risk areas or working tasks demand that workers must wear personal protective equipment (PPE) such as safety shoes.

The graph above indicates that existing measures especially in field of **fire and explosion protection** function to ensure the safety in and outside of a biogas plant.

3. Fire protection

Precautionary measures include:

a) Structural and technical fire protection
b) Organizational fire protection

Structural and technical fire protection integrates actions to:

- Use fire resistant classes of components (structural)
- Load-bearing capacity in the event of a fire (structural)
- Fire behaviour of materials (structural)
- Fire compartments (technical)
- Safe distance to paths and structures that do not belong to the plant, e.g., fire wall (technical)

Organisational fire protection includes measures like:

- Marking of areas

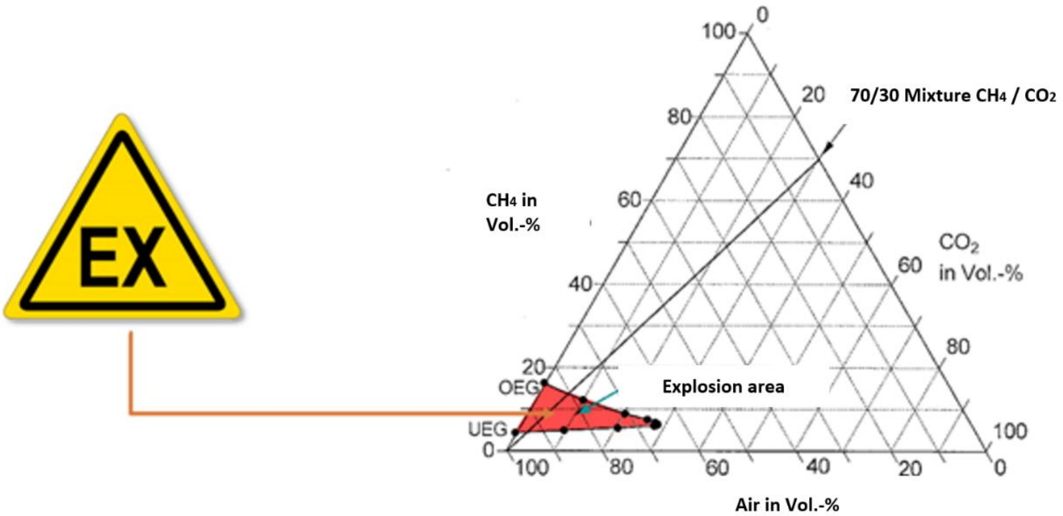


- Establishing rules of conduct for fire incidents, e.g.,
  a) Fire in the fermenter – *Do not extinguish if the gas supply has not been shut off. Separate residual gas in a controlled manner.*
  b) Fire in parts of the building – *Extinguish with water, foam, and/or CO_2 ; In particular, protect gas bearings from thermal radiation, flying sparks.*
- Signage in the biogas plant to support firefighters working in the case of an incident.
- Instruction to rescue workers regarding possible dangers such as fire, explosion, gas, electricity
- Installation of fire protection regulation signs visibly in the biogas plant
- External oil and waste storage to avoid and reduce fire loads
- Open and unobstructed escape and rescue routes
- Suitable extinguishing agents (fire extinguishers A, B, C and CO2 for electrical systems)
- Sufficient extinguishing water volume (800 l / min over 2 h = 48 m^3 / h)

4. Explosion protection

A methane-air mixture can ignite at 6-22 Vol%. An ignition is not possible below 6% (lower explosion limit) and above 22% (upper explosion limit). Only a small amount of ignition energy is required to trigger an explosion.

Picture 3. Explosion triangle



Source: (German) Safety requirements for biogas plants (TRAS) No. 120

Explosion protection at **agricultural biogas plants**: the concentration of methane is around 60%, carbon dioxide concentration around 40%, hydrogen concentration around 5%, and nitrogen concentration between 1 and 2% (Mohammadi, 2013). Another author is more detailed. Raw biogas usually consists of the following components [Z]:

- Methane (50 mol% to 80 mol%)
- Carbon dioxide (20 mol% to 50 mol%)
- Water vapor (0 mol% to 12 mol%)
- Nitrogen (0 mol% to 5 mol%)
- Oxygen (0 mol% to 2 mol%)
- Hydrogen sulphide (0.01 mol% to 0.4 mol% (100 to 4000 ppm(v)), and traces of ammonia, hydrogen, and higher hydrocarbons.

Other sources state maximum H_2S amounts up to 2 mol%.

From the point of view of danger of biogas deflagration, methane concentration is especially important.

The explosion region is limited by three points: UEL (upper explosion limit), LEL (lower explosion limit, and LOC (limiting oxygen concentration). See the table below (Schroeder et al, 2014).

Table 1: Explosion regions

	Biogas (60% CH_4; 38 % CO_2;	**Natural gas**	**Propane**	**Methane**	**Hydrogen**
Density [$kg \cdot m^{-3}$]	1,2	0,7	2,01	0,72	0,09
Ignition temperature [°C]	700	650	470	595	585
Explosion limits[%vol]	6–12	4,4–15	1,7–10,9	4,4–16,5	4–77

Source: Safety rules for biogas systems [online]. Sozialversicherung für Landwirtschaft, Forsten und Gartenbau, 2008

Measurement and control technology helps to constantly monitor the methane-air mixture in a biogas plant. In addition, the following measures are necessary:

- Leak tightness of system parts due to construction and maintenance measures as well as leak tests are negative.
- Avoidance of ignition sources:
    a) hot surfaces, hot gases, e.g., Exhaust gas chimney in a combined heat and power plant,
    b) mechanically generated sparks during welding,
    c) electrical equalizing currents and cathodic corrosion protection,
    d) static electricity - e.g., employees
    e) lightning strike
- Use of approved electrical equipment
- Explosion-proof construction gas storage
- Explosion-related decoupling of endangered areas, e.g., flame arrestors for buildings

To mark areas with no, lower, or higher risk, so called "**explosion zones"** or **EX zones** are defined and marked within a biogas plant by the following sign:

The following environments must be indicated:

a) Mixture of air and ignitable gas

Zone 0 - high and continuous risk of an explosive mixture of air and ignitable gases, vapours

Zone 1 – temporary risk of an explosive mixture of air and ignitable gases, vapours during regular operation

Zone 2 – no or short-term risk of an explosive mixture of air and ignitable gases, vapours during regular operation

b) Mixture of air and ignitable dust

Zone 20 – high and continuous risk of an explosive atmosphere in the form of a cloud of ignitable dust

Zone 21 – temporary risk of an explosive atmosphere in the form of a cloud of ignitable dust

Zone 22 - no or short-term risk of an explosive atmosphere in the form of a cloud of ignitable dust

For zones 0-1 or 20-22 relevant signs must indicate the relevant EX zones to the workers.

5. Risk of poisoning

Most of the poisonings that have occurred during the operation of biogas plants have so far been caused by the inhalation of hydrogen sulphide (H_2S). Hydrogen sulphide is a colourless gas with a highly toxic effect, especially for terrestrial organisms. Leaking it can be dangerous for all people in the immediate vicinity of the leak. This fact has been proven by some tragic incidents that occurred at biogas stations where leaks took place. The effects of hydrogen sulphide on the body always depend on many factors (e.g., humidity, temperature, sex of the individual, current health status of the individual, etc.) (Wexler, 2005).

Hydrogen sulphide toxicity is high. However, the hydrogen sulphide content of biogas is relatively low and largely dependent on the material that is processed in the biogas plant. Table 2 presents the concentrations of hydrogen sulphide in biogas which comes from different biogas plants and from different processed material. In general, it can be said that higher concentrations of hydrogen sulphide is shown in biogas which is produced by processing material of animal origin. However, sulphur also occurs naturally in plant bodies (e.g., in energy maize) (Trávníček et al., 2015).

Table 2: Concentration of H_2S in input material for anaerobic fermentation

Material (source)	**concentration**	**Author**
sewage sludge	25–75 ppm	Veselá et al., 2010
sewage sludge	< 10 ppm	KYMÄLÄINEN [et al., 2012
pork slurry	1 200 ppm	PIPATMANOMA et al., 2009
pork slurry	2 400 ppm	Silva et al., 2014
slurry	200 – 1 200 ppm	Urban et al., 2008
food sludge	500 – 6000 ppm	Pastorek et al., 2004

Source: Safety rules for biogas systems [online]. Sozialversicherung für Landwirtschaft, Forsten und Gartenbau, 2008

In Table 3, the toxic effects of H_2S to humans are shown depending on the gas concentration and exposure time to adverse effects.

Table 3: The toxic effects of H_2S to humans

Gas concentration	**Exposure time**
< 100 ppm	dangerous after several hours
100 ppm ≤ x < 500 ppm	dangerous after 30 min to 1 h
~ 500 ppm	life-threatening after 30 min
~ 1000 ppm	life-threatening after a few minutes
~ 5000 ppm	lethal in a few seconds
10-14 ppm	Conjunctivitis Burning eyes
14–25 ppm	Headache, loss of appetite, weight loss, and dizziness
~ 50 ppm for long time	Pulmonary edema
50–150 ppm (other sources 100-200)	Olfactory loss
250–600 ppm	Pulmonary edema

Source: http://www.umweltbundesamt.de

Hydrogen Sulphide (H_2S) also has corrosive effects on concrete and metal materials. During the combustion of biogas, sulphur dioxide is formed from it. During further oxidation sulphur dioxide, which dissolves in the condensate during the cooling of flue gases to sulfuric acid, is highly corrosive.

The concentration of H_2S in biogas is often expressed in different units, which make it difficult to find a clear orientation between the individual values.

Concentrations should be expressed for standard conditions, which in this case means:

- dry gas, e.g., dehumidified gas (water vapor),
- standard pressure, e.g., 101,3 kPa,
- standard temperature e.g., 273 K or 0 ° C
- (exceptionally also 15 ° C or 25 ° C)

The most used ways of expression are:

- (mg / Nm^3), (g / Nm^3) mg / m3, g / m3 (under standard conditions)
- volume percentage (vol.%)
- ppm units - "parts per million"

The relationship between the listed units under standard conditions:

0.1 vol.% = 1,000 ppm = 1,517 mg / m^3

H_2S can be removed by technological interventions; internal removal of sulphides in an anaerobic reactor or external removal of H_2S from biogas.

Technological interventions

Maintaining the reactor pH at 8, when 90% of the sulphides are dissociated at 50%, pH at 7.

This means limiting all influences that could cause the pH to drop, such as:

- Sudden overload of the system with the formation of fatty acids
- Mixing failure or insufficient mixing
- Impact increase in the input amount of sulphur in any form

Internal removal

- Takes place either by precipitation of sulphides by addition of an iron reactor;
- By biological oxidation of sulphur in situ - limited supply of air or oxygen directly to the anaerobic reactor; solid sulphur is formed, which is removed with the sludge. Air is metered directly into the fermentation mixture at the gas-liquid interface

External H2S removal - much more is said in the section "Composition and Treatment of Biogas"

- Physico-chemical - Sorption, washing
- Chemical - precipitation
- Biological - use of sulphur bacteria

Another gas contained in biogas that can cause poisoning is carbon dioxide. Carbon dioxide is heavier than air and can be collected, for example, in condensing shafts or in fermenters whose contents have been discharged (e.g., due to repairs or maintenance) but without sufficient ventilation. As stated by the European Association of Industrial Gases (European Industrial Gases Association, EIGA), carbon dioxide intoxication cannot be confused with suffocation. Oxygen measurement (e.g., by service personnel) is not an indicator of the risk of death. For example, the release of carbon dioxide into the air may slightly reduce the oxygen concentration to 19%. This value itself is not harmful in any way. However, if the concentration of carbon dioxide increases to 9.5%, it is a serious health hazard for those present [S]. The health effects of elevated CO_2 concentrations are listed in Table 4.

Table 4: the toxic effects of CO_2 to humans

Concentration of CO_2	**Effect**
1–1,5 %	After several hours of exposure, mild effects on chemical metabolism occur.
3 %	The gas is slightly narcotic at this concentration, causing deep breathing, impaired hearing and headaches, increased blood pressure and faster heart rate.
4–5 %	The respiratory centre is stimulated, which leads to accelerated, deep breathing. Signs of poisoning begin to appear after 30 minutes of exposure.
5–10 %	Breathing is more strenuous; the sufferer has a headache and loses the ability to judge.
≥10 %	If the concentration of carbon dioxide is higher than 10%, unconsciousness occurs within one minute, and if no immediate action is taken, further exposure to such high concentrations will lead to death.

Source: http://www.umweltbundesamt.de

6. Further risks

Before and during operation of a biogas plant further risks and dangers must be considered:

a) Emission thresholds of e.g., biogas engines (> 1000 kW), plants for processing raw biogas (>1,2 Mio. Nm^3 Biogas per year), storage of digestate (>6.500 m^3) before erecting or before alterations of biogas plant machinery

b) Dangers such as:

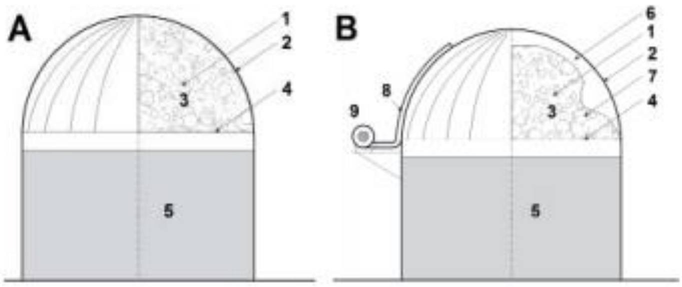
- Technical sources of danger (e.g., ignition sources, pollution, corrosion, failure of process control equipment)
- Material sources of danger (e.g., biogas and its components, substrates (waste), auxiliaries and additives, liquid, and solid fermentation products)
- Other sources of danger (e.g., inadequate safety culture, failure to follow safety rules, maintenance errors, material confusions)
- Environment related sources of danger (e.g., extreme temperatures, lightning strikes, floods, wood fires)

7. Example: Safety of biogas gasholders

The decisive criteria for choosing the design solution include the working pressure, the storage volume, the external load, and the number and size of the tanks. Biogas tanks can be operated as low pressure (overpressure up to 5 kPa) or high pressure (overpressure 5-400 kPa). In any case, it must be gas-tight, resistant to UV radiation, temperature changes, and weathering. The volume of storage tanks depends on the biogas production in the biogas plant and can reach up to 16,000 m3.

In Europe, basically two basic solutions are used for the construction of biogas storage tanks: an integrated storage tank or a free-standing storage tank. In most cases, the container consists of a single-layer or double-layer polyester membrane, which is covered on both sides with laminated PVC. Some manufacturers also offer a three-layer membrane. The integrated biogas storage tank is the simplest and most widespread solution. In this case, the tank is located at the top of the fermenter. The membrane is protected against falling into the substrate by means of straps or by means of a wooden ceiling, which is placed above the surface of the substrate in the fermenter. The tank is protected against excessive overpressure by a liquid fuse. An embodiment of an integrated single-membrane and double-membrane container is shown in Picture 4.

Picture 4: Scheme of single-membrane (A) and double-membrane (B) integrated biogas storage



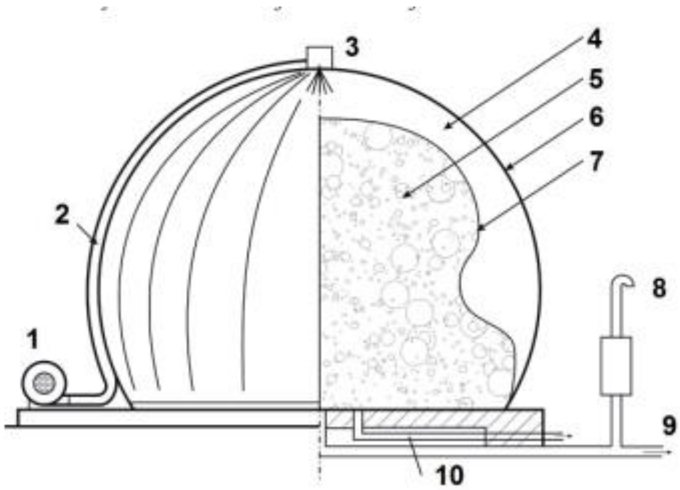
Source: https://docplayer.cz/198056318-Bezpecnost-bioplynovych-stanic.html

1 - gas space, 2 - outer membrane, 3 - biogas, 4 - straps, ceiling, 5 - fermented material, 6 - air space, 7 - inner membrane, 8 - air supply, 9 - fan

The two-membrane biogas tank consists of an external protective membrane and an inner membrane which serves as a cover for the fermenter. The biogas pressure in the tank is regulated by air, which is blown between the two membranes by a fan. This air fulfils two functions: on the one hand it maintains the overpressure of the biogas and on the other hand it keeps the shape of the outer membrane constant. The stable shape of the tank significantly contributes to the reduction of complications in case of adverse weather conditions (snow and wind). The measurement of the tank filling level is ensured by an ultrasonic sensor located at the top of the air space. The tank is protected against excessive overpressure by a liquid fuse. The fermenters are also equipped with a pressure control valve.

Freestanding spherical biogas tanks are formed by an outer, inner, and floor membrane, which are fixed to the reinforced concrete base plate by an anchor ring. The floor membrane seals the gas space against a reinforced concrete base. The outer diaphragm has the shape of a spherical canopy and is tensioned by overpressure of air from the support fan. The movable inner membrane forms a variable gas space with the floor membrane and, together with the tensioned outer membrane, a pressure control space. A support fan connected by an air hose to the outer membrane generates the required biogas overpressure by pressing air on the inner membrane. The tank is protected against excessive overpressure by a liquid fuse. If the gas production is higher than the consumption, the volume of the gas space increases at the expense of the pressure control space and vice versa. The overpressure in the gas system is given by the pressure created by the support fan. An ultrasonic position sensor of the inner membrane is used to check the filling of the biogas tank. The free-standing tray is shown in Picture 5.

Picture 5. Freestanding spherical biogas storage tank



Source: https://docplayer.cz/198056318-Bezpecnost-bioplynovych-stanic.html

1 - fan, 2 - pressure hose, 3 - ultrasonic filling sensor, 4 - air space, 5 - gas space, 6 - outer membrane, 7 - inner membrane, 8 - liquid fuse, 9 - biogas drain, 10 - condensate drain.

Another solution for biogas storage can be gas bags, which are hung on a steel structure. They then have pipes connected in their front wall for the supply and discharge of biogas. There is a condensate outlet at the lowest point of the bag. In the upper part there are suitable weights to help empty the bag. To protect the tank against impermissible overpressure, the supply line must be fitted with a liquid safety device. The biogas bag is usually placed in a shelter that protects it from the weather and mechanical damage, or it is hung directly in the biogas plant building. Biogas can also be stored in steel atmospheric tanks. This type of storage tank is used mainly at biogas plants located at wastewater treatment plants.

In this respect, the work of James Chang is interesting, which maps a total of 242 tank accidents that have taken place over 40 years [3]. Chang lists the following causes of tank accidents:

- Lightning - a total of 33% of accidents on storage tanks were caused by lightning, which took first place among all the causes of monitored accidents. (An accident at a biogas storage tank caused by an atmospheric discharge occurred in the Czech Republic, for example, in 2011. Due to the physical effect of the lightning, a fire broke out and a partial explosion occurred on the technological equipment. As a result of the accident, the membrane of the integrated container ruptured and subsequently fell into the fermented material. The construction of the fermenter was made of reinforced concrete, there was no obvious damage to the reinforced concrete fermenter as a result of the accident).

- Maintenance Error - maintenance error is attributed to approximately 13% of the monitored accidents. Initiation occurs during welding, heat generation due to mechanical friction, or electrical sparking.

- Operating Error - overfilling or over pressurization of the tank from the available sources. It is not known if a situation of tank overpressure would result in leakage of biogas and subsequent initiation or poisoning of personnel.

- Sabotage - not a typical target of sabotage

- Equipment Failure - from the available data, however, it is not known that a case of combustion or explosion of biogas would occur due to the failure of the technical equipment of the storage of a biogas plant.

- Crack and Subsequent Burst - In the Czech Republic, and therefore in Europe, most biogas plants are up to 20 years old. The probability of biogas leakage due to the above-mentioned causes is therefore relatively low during normal operation. The damage occurs rather due to external influences, such as extreme weather conditions or careless driving with handling equipment.

- Static Electricity - ignition of the mixture due to electrostatic electricity occurs most often during the transport of fluids through pipelines, when the charge may accumulate, or when unsuitable tools are used during pumping, etc. In the available data we do not find a case of static gas subsequent fire or explosion.

- Open Flame - for example, a residual biogas burner or a lit cigarette.

- Natural Disasters - ranked from the most common: lightning, floods, low temperatures, rain, strong winds, landslides, high temperatures, earthquakes.

- Uncontrolled Reaction - biochemical processes are in principle not so fast that there can be rapid heat generation and subsequent explosion or burning of biogas.

In the Czech Republic, the safety elements of biogas plant storage tanks are dealt with in the technical recommendation TDG 983 02: Gas Management of Biogas Plants, issued in 2013 by the Czech Gas Association. The technical standard TPG 703 01, part IV: Biogas Gas Pipelines then applies to the design of raw biogas distribution systems. The technical standard ČSN 75 6415: Gas Management of Wastewater Treatment Plants is also partially devoted to biogas storage tanks.

Fire in a biogas plant on 04.05.2021

During the fire at the biogas plant in Dětřichov near Moravská Třebová, 200 km east of Prague, one gas tank exploded, injuring three people. "One of the tanks exploded and a thick plastic sheet placed on the damaged tank flew to about a hundred meters. During the explosion, three people were injured, who either inhaled toxic combustion products or got burned," said firefighter spokeswoman Vendula Horáková.

8. Rules for biogas plant control during operation

- List of processed raw materials,
- Description of raw material handling,
- In case the input raw material will be transported from a place other than the one operated by BPS, it is necessary to clearly specify the transport routes and also to specify the collection distances,
- Description of process control, temperature, and operating regimes for specific raw materials being processed (pH, laboratory controls, ammonia concentration, digestion time, etc.),
- Method of incorporation (start-up) of the process description and frequency of monitoring critical points according to HACCP for processes subject to pasteurization and sterilization. It is necessary to state the temperature, pressure, heat treatment time, and size of processed particles,
- Detailed description of operation and risks, resp. emergency situations at the sterilization unit. A separate operating rule would be appropriate,
- Description and frequency of laboratory controls of fermentation residue,
- Description of the handling of the fermentation residue. In case of transfer of the fermentation residue to another subject, keep records of when, how, to whom, and how much was shipped,
- Emergency plan in terms of the collapse of the biogas plant disposal of excess raw material, cleaning, and start-up of BPS and additional equipment,
- Contractual provision of export and processing of raw material and mixture from the reactor by another entity in case of accident,
- Activated carbon filters are not suitable for the elimination of odorous substances in BPS operations.

As part of the continuous operation of a biogas plant, we recommend the following from the point of view of air protection:

- After the start-up of the technology, perform hydrogen sulphide (H2S) and ammonia (NH3) emissions measurements once a year at the outlet of the installed biofilter in accordance with the existing standards for measuring emissions of these pollutants,
- After starting the technology with enough developed biogas perform a new authorized emission measurement behind the cogeneration unit TEDOM Quanto D500 SP BIO in the range of solid ZL, VOC as TOC, NOx and CO including determination of sulphur content in biogas,
- After starting the technology with sufficient amount of developed biogas perform a new authorized measurement of odorous emissions from the biofilter and at the boundary of the plot by a set date at the latest, with the proviso that this measurement will be carried out in the summer, e. g. in the period (May to July),
- Regularly check the tightness of sumps and integrity of membranes for biogas collection so that unnecessary emergency conditions do not leak odorous substances,
- In case of handling digestate as an organomineral fertilizer, this fertilizer must be immediately incorporated into the soil with the latest technologies so as not to bother the population with secondary development of possible odorous substances,

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- Operate a biogas plant so that complete decomposition of biological material and thus the decomposition of this digestate on the surrounding fertilized land was prevented and thus secondary odour emissions prevented,
- During operation it is necessary to observe especially conditions for minimizing operational leaks of harmful substances and basic requirements for handling individual harmful substances in relation to possible accidental leaks.

General requirements for the operation of a biogas plant according to the methodological instruction of the Ministry of the Environment of the Department of Air Protection for the approval of biogas plants for operation:

- Unambiguous definition of the type of fermentation process (mesophilic, thermophilic fermentation) This is also related to ensuring the stability of the composition of the input raw materials (input mix) and the principles for the smooth implementation of changes and their permissible level. These conditions must be stated and justified in the project documentation,
- For anaerobic digestion of bio-waste in all types of facilities with expected sanitized output, a minimum temperature of 55 ° C of treated bio-waste must be maintained and maintained for at least 24 hours without interruption and the total duration of the anaerobic digestion process must not be less than 30 days. Shorter residence times (at least 20 days) are only permitted for installations where the stability of the reclamation digestate has been verified by AT4 and GS 21 methods (OENORM S 2027-1 and 2 / 01-09-2004).

The requirement to maintain a minimum temperature is not required if the treated biowaste is only plant tissues. In case the operating temperature in the reactor is lower than 55 ° C or for a shorter exposure time of the reactor charge at this temperature, it is necessary that:

- biowaste is pre-treated at 70 ° C for 1 hour, or
- recultivated digestate is subsequently treated at 70 ° C for 1 hour, or
- reclamation digestate is composted.

9. Quiz

This module contains a quiz. The quiz can be answered on-line, by using QR code below. The student receives per question an answer of either **correct** or **incorrect** and has to correct each wrong answer before proceeding to the next question.

(Scan with your Smartphone camera / QR Code reader app to access the quiz)

1. Occupational health and safety includes?

a. A bundle of orders to protect solely the employer
b. A bundle of measures, means, and methods to protect the employees

Answer: b

2. The "TOP" principle stands for?

a. Time, order, party measures
b. Time, order, person measures
c. Technical, organisational, person-related measures

Answer: c

3. Health and Safety (H&S) must be carried out?

a. Precautionary
b. Continuous
c. Precautionary and continuous

Answer: c

4. Fire protection involves? (Multiple answers**)**

a. Marking of areas
b. Establishing rules of conducts for fire incidents
c. Instruction of rescue workers
d. Suitable extinguishing agents
e. *Sufficient extinguishing water volume*
f. *External oil and waste storage to avoid and reduce fire loads*

Answer: all are correct

5. An explosion triangle for a biogas plant defines the risk of ignition of?

a. A Methane-CO2-Air mixture
b. A Methane-CO2-water mixture
c. A Methane-Air-Water mixture

Answer: a

6. A so-called "Ex-Zone" stands for?

- *a. Expert zone*
- *b. Explosion zone*
- *c. Extreme zone*

Answer: b

7. Risk of poisoning for employees exist for? (Multiple answers)

- *a. Hydrogen sulphide*
- *b.* CO_2

Answer: a + b

8. During the operation of a biogas plant which technical dangers can occur? (Multiple answers**)**

- *a. Ignition of sources*
- *b. Pollution*
- *c. Failure of process control equipment*

Answer: a + c

9. Which other sources of danger might exist? (Multiple answers**)**

- *a. Inadequate safety culture*
- *b. Maintenance errors*
- *c. Failure to follow safety rules*

Answer: a + c

10. Sources

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- 510 (Storage of liquid and solid hazardous substances in portable containers,
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- 751 (Avoidance of fire, explosion and pressure hazards at petrol stations and gas filling systems for filling land vehicles).