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## ASSESSMENT OF BIOGAS POTENTIAL HAZARDS

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**ABSTRACT:** This article discusses the issue of hazards associated with the operation of biogas plants. Biogas produced from anaerobic fermentation of organic substances represents an alternative renewable energy source. With this operation is linked the potential danger of explosion, requiring the inclusion of various parts of facility in the explosions zones which give rise to additional security measures. Biogas plant may also have potential dangerous impact on human health and the environment.

**KEYWORDS:** Biogas, risk assessment, explosion risk, fire risk, health risk

### INTRODUCTION

Biogas production from agricultural, municipal, and industrial wastes can contribute to sustainable energy production, especially when nutrients conserved in the process are returned to agricultural production (Figure 1). Little energy is consumed in the process, and consequently the net energy from biogas production is high compared to other conversion technologies. The technology for methane production is scalable and has been applied globally to a broad range of organic waste feedstocks, most commonly animal manures (Wall et al., 2008). The main hazards associated with biogas productions are potentially explosiveness, asphyxia, toxicity and disease (Westerman et al., 2007).

There are two main types of biogas: “landfill gas”, which is formed spontaneously in domestic waste landfills and “digester gas”, which is induced in bioreactors or digesters (Dupont, Accorsi, 2006).

Table.1 Possible biogas composition (Naskeo, 2009, Saija, 2009)

Compound	Chemical formula	Vol. (%)
Methane	CH <sub>4</sub>	50–75
Carbon dioxide	CO <sub>2</sub>	25–50
Nitrogen	N <sub>2</sub>	0–10
Hydrogen	H <sub>2</sub>	0–1
Hydrogen sulfide	H <sub>2</sub> S	0–3
Oxygen	O <sub>2</sub>	0–1
Ammonia	NH <sub>3</sub>	0–1
Water	H <sub>2</sub> O	0–10

### BIOGAS RISK ASSESSMENT. Explosion risk assessment

Many workplaces may contain, or have activities that produce, explosive or potentially explosive atmospheres. Such a workplace is also biogas plant. Methane, which makes up from 50% to 75% of biogas, forms explosive mixtures in air, and presents serious explosion danger. The lower explosive limit of methane being 4,4 vol. % and the upper limit 16,5 vol. % (Siemens, 2010). Under and upper this limits methane cannot be ignited under normal ambient circumstances.

Explosions can cause loss of life and serious injuries as well as significant damage. Preventing releases of dangerous substances, which can create explosive atmospheres, and preventing sources of ignition are two widely used ways of reducing the risk (Health & Safety Executive, 2010). European

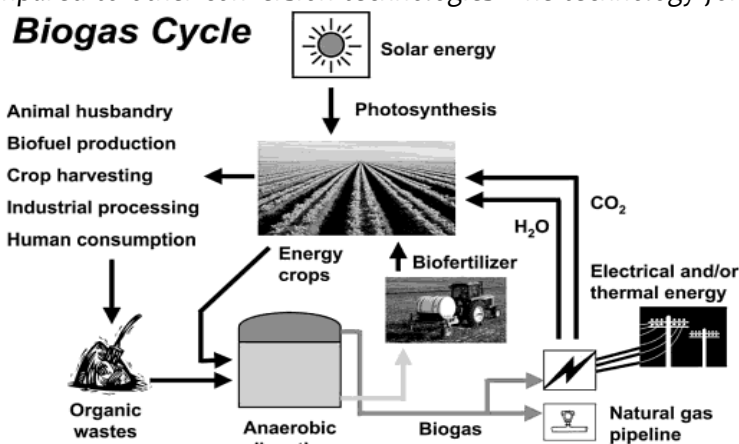


Figure 1. Biogas cycle (Wall et al., 2008)

Biogas composition depends considerably on waste nature and processes and also varies in time (Table. 1). However, it is mainly composed with methane (CH<sub>4</sub>) and carbon dioxide (CO<sub>2</sub>) (Dupont, Accorsi, 2006). It also contains traces of many other compounds, especially hydrogen sulfur (H<sub>2</sub>S) or/and organosulphur (mercaptans) in small contents (Dupont, Accorsi, 2006).

Directives for controlling explosive atmospheres is named ATEX. ATEX contain two directives (Health & Safety Executive, 2010):

- 1) Directive 99/92/EC (also known as 'ATEX 137' or the 'ATEX Workplace Directive') on minimum requirements for improving the health and safety protection of workers potentially at risk from explosive atmospheres.
- 2) Directive 94/9/EC (also known as 'ATEX 95' or 'the ATEX Equipment Directive') on the approximation of the laws of Members States concerning equipment and protective systems intended for use in potentially explosive atmospheres.

Spaces with risk of explosion are graded in zones according to the probability of the occurrence of a dangerous explosive atmosphere. If a dangerous explosive atmosphere can occur in a space, the entire space is to be regarded as highly explosive (Figure 2).

**Zone 0** covers spaces with a constant, long-term, or frequent (most of the time) dangerous explosive atmosphere which consists of a mixture of air and gases, vapors, or mists.

In biogas plants, the gasholder, the air intake of the combustion engine, the combustion chamber of the gas flare, and under special operating conditions the bioreactor itself belong to zone 0. A special operating condition is given when air enters the interior of the bioreactor. Under normal operation conditions, a small positive pressure prevents the penetration of air into the bioreactor.

In the air intake of the combustion engine or in the combustion chamber of the gas flare there is constantly an explosive mixture. The engine and the gas flare must be separated from the other gas system by a flame trap as safety device (Deublein, Steinhauser, 2008).

**Zone 1** covers spaces with the occasional occurrence of an explosive atmosphere which consists of a mixture of air and gases, vapors, or mists.

In conditions of good ventilation, zone 1 is to be assumed in a region within 1 m from components of the plant, items of equipment, connections, sight glasses, grommets, and service openings at the gasholder and at the bioreactor, but only if leakage of biogas is technically possible. Likewise the space around the mouth of exhaust pipes, positive pressure safety devices, and gas flares is considered to be zone 1. In closed spaces, the endangered space is extended to a periphery of 4.5 m.

Enclosed spaces or pits through which anaerobic sludge flows belong to zone 1. (Deublein, Steinhauser, 2008).

**Zone 2** covers spaces where the occurrence of dangerous atmospheres from gas mixtures cannot be assumed, but if it does occur it is seldom and only for a short time. Zone 2 is in the region 1 – 3 m from components of the plant technically classified as leak-tight, items of equipment, connections, grommets, service openings, and bursting disks. Open pits (e.g., pits for pumps for anaerobic sludge) or basins, enclosed spaces wherein gas pipes are installed and which do not have ventilation, are zone 2.

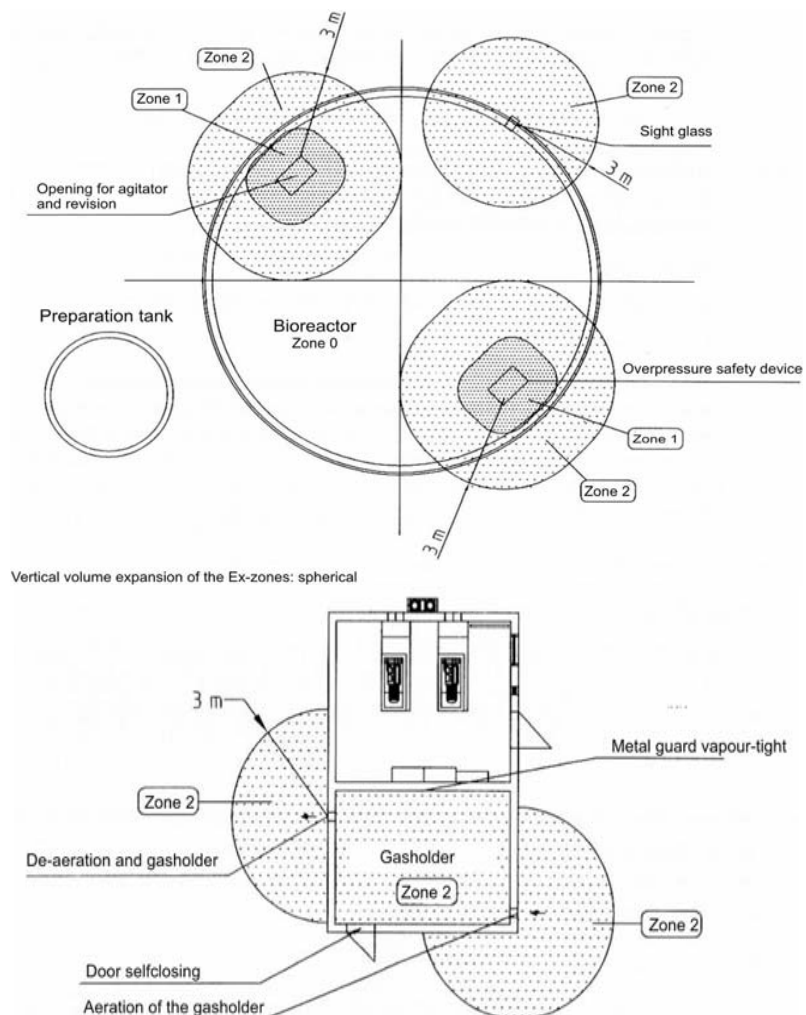


Figure 2. Explosive areas in biogas plants (Deublein, Steinhauser, 2008)

The radius of 1 – 3 m is given for good ventilation. Closed spaces are considered to belong to zone 2 in their entirety (Deublein, Steinhauser, 2008).

Operating staff on biogas plants should ensure that no air is allowed to enter the digester or gasholder. All piping and equipment must be sealed properly to prevent gas from escaping to the outside. There must be no smoking and all electrical installations, including light switches, torches etc. must be of the explosion-proof type, as the smallest spark could ignite escaped gases (Russel, 2007).

### Fire risk assessment

In order to reduce the fire risk, the plant is to be divided into fire protection sectors, e.g., the bioreactor and gasholder, the gas consumption equipment, and the gas compressor. Certain distances must be maintained between the fire protection sectors (Table 2-4). Depending upon how much space is available in between, the material of the external walls of buildings containing equipment or of protecting walls has to be chosen.

Table 2. Protection distances around above - ground fixed gasholders (Deublein, Steinhauser, 2008)

Gas volume per tank (m <sup>3</sup> )	Up to 300	300 to 1500	1500 to 5000	Over 5000	Material of the walls
Fire brake (m)	6	10	15	20	Other materials, class B
Fire brake (m)	3	6	10	15	Noncombustible, class A
Fire brake (m)	3	3	6	10	Fire retardant, vapor tight

Table 3. Protection distances around underground and earth - covered gasholders (Deublein, Steinhauser, 2008)

Gas volume per tank (m <sup>3</sup> )	Up to 300	300 to 1500	1500 to 5000	Over 5000
Fire brake (m)	3	6	10	15

Table 4. Protection distances around cushions and balloon gasholders as well as around foil hoods for gas holding above liquid manure storage tanks or bioreactors (Deublein, Steinhauser, 2008)

Gas volume per tank (m <sup>3</sup> )	Up to 300	300 to 1500	1500 to 5000	Over 5000
Fire brake (m)	4,5	10	15	20

### Health risk assessment

Each of these components of biogas has its own problems, as well as displacing oxygen (University of Adelaide, s.a.).

Methane (CH<sub>4</sub>) is a inert, colorless, odorless gas, lighter than air (will collect in roof spaces etc). In terms of health effects it is stifling gases and the most serious threat to health and life is choking expect explosion. At low concentrations can act narcotic. Victim may not be aware of asphyxiation, and when concentration arises can result in suffocation.

Carbon dioxide (CO<sub>2</sub>) is a inert, colorless, odorless gas, heavier than air (will collect in sumps etc.). If air with increased CO<sub>2</sub> contents no more than 3% CO<sub>2</sub>, toxic effects do not occur if the air contains enough oxygen. When increasing concentrations occurs, form anoxia and hypoxia, concentrations CO<sub>2</sub> above 5% affect respiration rate and irritation of respiratory tracts.

Hydrogen sulfide (H<sub>2</sub>S) is a flammable gas, which can recognize by smell at concentrations of 1.4 to 2.3 mg. m<sup>-3</sup> (rotten egg gas), destroys olfactory (smelling) tissues and lungs, and becomes odorless as the level increases. Impact on human is listed in Table 5 (Horák et al., 2007).

Table 5. Toxicity of hydrogen sulfide (Deublein, Steinhauser, 2008)

Concentration (in air)	Effect
0.03 – 0.15 ppm	Threshold of detectability (odor of bad egg)
15 – 75 ppm	Irritation of the eyes and the airways, nausea, vomiting, headache, unconsciousness
150 – 300 ppm (0.015 – 0.03%)	Palsy of the olfactory nerve
> 375 ppm (0.038%)	Death through poisoning (after some hours)
> 750 ppm (0.075%)	Unconsciousness and death by apnea within 30 – 60 min
Above 1000 ppm (0.1%)	Sudden death by apnea within a few minutes

### Noise

Noise is defined to be disturbing sound. Any location where sound does not cause disturbance, even it is very loud, does not incur restrictions. The area in a biogas plant where noise is most intense is near the gas engine. Near CHP plants, the limiting value 80dB (A) for workplaces is far exceeded. The noise radiates through the exhaust pipe and the ventilation openings of the plant area (Deublein, Steinhauser, 2008). Safety arrangements (Deublein, Steinhauser, 2008):

- The operation of engines, machines, and plant must correspond to the state of the art of noise protection.



- Impact sound - radiating plants must be decoupled from airborne sound - radiating buildings and components.
- In exhaust gas pipes and/or in openings for ventilating enclosed spaces, sound absorbers have to be installed.
- Doors, gates, and windows of the generator house must be closed when the engine is under load.
- The space close to the generator house must be noise - protected by sound - damping measures according to local regulations.

### Disease

As Anaerobic Digestion relies on a mixed population of bacteria of largely unknown origin, but often including animal wastes, to carry out the waste treatment process care should be taken to avoid contact with the digester contents and to wash thoroughly after working around the digester (and particularly before eating or drinking). This also helps to minimize the odors spread which may accompany the digestion process. The digestion process does reduce the number of pathogenic (disease causing) bacteria, particularly at higher operating temperatures, but the biological nature of the process need to be kept in mind (University of Adelaide, s.a.).

### Water pollution

A big danger to the environment arises when water, e.g., from pressing plants or contaminated precipitation water, penetrate into the soil or, even worse, reach the groundwater. Main causes can be:

- insufficiently tightened ground within the plant site
- cracks in tanks and/or in the crankshaft housing
- corrosion of pipework (Deublein, Steinhauser, 2008).

To eliminate this hazards the best available measures must be taken in biogas plants to protect water from contamination and even more from unfavorable changes of water at any place.

### CONCLUSIONS

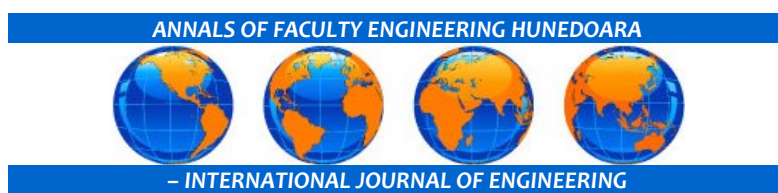
In this contribution are mentioned some hazards which do not cover all the security risks associated with the operation of biogas plants. During operation, are particularly important regular checks on which to keep records, operational safety features for the possibility of early detection of potential danger, regular staff training and compliance legal and technical regulation.

### Acknowledgement

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