REQUIREMENTS OF CONTROL INSTRUMENTS FOR SAFETY OPERATION OF BIOGAS PLANTS AND OF LIVESTOCK FARMS

T. VOJTELA, J. BAK, L. FENYVESI
Hungarian Institute of Agricultural Engineering (MGI)
Tessedik S. u. 4., Gödöllő, H-2100, Hungary
Tel.:+36 28 511-632, E-mail: vojtela.tibor@gmgi.hu

Abstract

Different gases originated from biogas plant can damage: – the health of the workers (labor hygiene effect), – the health and production of the animals of the neighboring livestock farm (animal health effect), – as well as can pollute the environment (ambient influent effect). The aims of this article are to provide current information: – about requirements for instruments of biogas plant and livestock farm, – about gas concentration limit vales related to environmental, labor hygiene and animal health effect.

Keywords

polluting gases, labor hygiene effect, animal health effect, ambient influent effect, requirements for control instruments

Introduction

The energy production, connecting to livestock farms happen in biogas-plants utilizing livestock manure originated from animal farms, begins nowadays in Hungary. The occasionally leaking biogas from biogas plant comprises: - 50-75 % methane (CH_4), - 30-45% carbon dioxide (CO_2), - and 2-8% other trace gases (O_2, N_2, H_2S, water vapor) (Bense. et al., 2009). In the case of cattle manure fermentation the biogas yield is only 0,56-1,5 m^3/animal unit/day. In the case of 50 % manure + 50 % maize silage fermentation the biogas yield is higher 1,2 – 3 m^3/animal unit/day. In the case of 10 % probable biogas leakage, that means 24-72 m^3/day methane and 15-40 m^3/day carbon dioxide exhausted to the ambient air. A dairy cow‘s annual carbon dioxide production is approximately 4 t/year, that means 5-6 m^3/day/cow carbon dioxide production daily. Out of gases mentioned before the exhaust gases of biogas engines contain carbon dioxide and water vapor (plus other trace gases: sulfur dioxide, nitric oxide, carbon monoxide, hydrocarbons, carbon black), and these are also out let gases to the ambient air. Theoretically the air demand of biogas engine for complete combustion is 5,7 m^3 air/m^3 biogas. The emission limit values of biogas plants are defined in case of particulate matter (PM), carbon-monoxid (CO), sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and ozone (O_3) (Rasi et al., 2006). Each gas of biogas plant has separately effects but the gases included by biogas have common labor hygiene effect, animal health effects and ambient influent effect, and that is why it is so important to us to consider these interactions.

Materials and methods

Before entering biogas plant drains or for revision works in slurry containers (Figure 1.), multi-gas detectors must be used to protect personnel against combustible and toxic gases.

The following hazards must be monitored:

– Methane gas (CH_4) and air mixture, to prevent an explosion.
– Oxygen (O_2) deficiency, to make sure that entering without a breathing mask is possible.
– Hydrogen sulfide (H_2S), which builds up if organic processes are carried out without oxygen. Even small concentrations of hydrogen sulfide are toxic and act as a neurotoxin.
– Ammonia (NH_3) detection in the air means monitoring of animal houses in which animals and people work. The positive thing about small ammonia concentration that people recognize it by its unpleasant odor.
– Carbon dioxide (CO_2), a gas that builds up in all organic processes and, under certain geologic circumstances, even diffuses into a drain from the liquid manure or from a balance reaction with water.

The good confined space gas detector doesn’t come from any one manufacturer; it’s the instrument that good fulfills the requirements for confined space program of biogas (Figure 2) and livestock farm (Henderson, 2007); (Kleine, 2007); (Rasi et al., 2006).

Figure 1. Slurry container neighbor of a biogas plant (Source: own collection)

Figure 2. Biogas-plant built in the neighbor of dairy farm. (Source: own collection)

Results and discussions

Sensory organs of people do not feel the increase of CO_2 concentration in the ambient air (Table 1.). Livestock Farm + Biogas Plant = concentrated CO_2 emission place. Production decrease in pig and poultry houses at 0,5 – 0,6 % CO_2 concentration. Measuring range needed in animals’ buildings 0 to 20 /Vol.-% CO_2/.

Sensory organs of people feel already the 5-50 ppm NH_3 concentration in the ambient air (Table 2.). Pig Farms have considerable quantity NH_3 emission. Measuring range needed in animals’ buildings 0 – 100 ppm NH_3 concentration.

Sensory organs of people feel already the 0,01-0,7 ppm H_2S concentration in the ambient air (Table 3.). Measuring range needed in animals’ buildings 0 – 100 ppm H_2S concentration.

Sensory organs of people do not feel the increase of CH_4 concentration in the ambient air (Table 4.). Methane is a combustible gas. There is no measuring range needed in animals’ buildings methane concentration.

Sensory organs of people can feel biogas, if it contains minimum 0,01-0,7 ppm H_2S (Table 5.). The presence of biogas is clearly and in time recognizable about the odor of rotten egg (because of the hydrogen sulfide) in the breath of air. Biogas in air can explode (EXPLOSION RISK), and can flames up (FIRE HAZARD).

Table 1. Carbon dioxide (CO_2) in the ambient air at Livestock Farm and Biogas Plant

Designation	Data, feature
Volume mass:	1,9768 kg/m^3 (1.5 times heavier than air).
Colour, odour:	- colourless, - odourless.
CO_2 accumulates in layers of air being near the flooring of deep lying and in sealed rooms.	
Main resources:	- the exhaled air by livestocks,
	- the decaying faeces and urine (e.g. in slurry tank),
	- the leaking biogas contains 25-50 % CO_2 (e.g. from the fermentor),
	- the exhausted gas of motor fuelled by biogas.
Effects of accumulating CO_2 concentration	- decreasing oxygen level in the air,
	- difficulties, in animals' and peoples' air changing.
Effects of increasing CO_2 concentration in the ambient air to the people	
0,03 % CO_2	fresh air,
0,07 % CO_2	ambient air in cities,
1 % CO_2	short term exposure level (STEL),
1 – 2 % CO_2	sleepiness,
near 3 % CO_2	headache, retching,
near 10 % CO_2	leading to comas,
near 20 % CO_2	dead in a few seconds,
0,3 % CO_2	EU-s threshold limit value (TLV) in animals' buildings and people's workplace.

Table 2. Ammonia (NH_3) in the ambient air at Livestock Farm and Biogas Plant

Designation	Data, feature
Volume mass:	0,7715 kg/m^3 (lighter, than air).
Colour, odour:	- colourless, - typical unpleasant odour.
Lyses:	properly lyric in water.
NH_3 is spread evenly in the ventilated air.	
Main resources:	- the decaying faeces and urine (e.g. in slurry tank),
	- the undigested feeding in faeces.
Effects of accumulating NH_3 concentration:	- shedding of tears, frequent sneezing, frequent coughing,
	- respiratory diseases.
0,002 % (20 ppm) NH_3	EU-s threshold limit value (TLV) in animals' buildings and people's workplace.
100 ppm NH_3	so unpleasant, that people start to panic.
17 Vol.%, NH_3	lower explosion limit (LEL) of ammonia.

Table 3. Hydrogen sulfide (H_2S) in the ambient air at Livestock Farm and Biogas Plant

Designation	Data, feature
Volume mass:	- heavier, than air.
Color, odor:	- colorless, - its odor reminds people to odor of rotten egg.
Main resources:	- from the anaerobic degradation of protein,
	- from slurry channel being under the slatted floor,
	- the leaking (not sculptured) biogas contains 0,1-1,0 % H_2S (e.g. from the fermentor).
Effects of accumulating H_2S concentration:	- irritation to mucous membrane , - bronchitis,
	- very strong toxic effect, - pneumonia.
Effects of increasing H_2S concentration in the ambient air to the people:	
0,01-0,7 ppm H_2S	people can already feel the odor,
3-5 ppm H_2S	people feel intolerably and uncomfortably themselves,
10 -15 ppm H_2S	during several hours H_2S causes conjunctiva and mucous membrane irritation,
50-100 ppm H_2S	within one hour it causes conjunctiva and mucous membrane irritation,
0,5 ppm H_2S	EU-s threshold limit value (TLV) in animals' buildings and people's workplace.

Table 4. Methane (CH_4) in the ambient air at Livestock Farm and Biogas Plant

Designation	Data, feature
Volume mass:	0,7168 kg/m^3 (lighter, than air).
Color, odor:	- colorless, - odorless.
CH_4 is spread evenly in the ventilated air. Methane and air can create an explosive mixture.	
Main resources:	- originates from ruminants within rumen-fermentation, it exhausts as flatus to the air of stable,
	- the leaking biogas contains 50-75% CH_4 (e.g. from the fermentor, from the biogas pipeline).
Effects of accumulating CH_4 concentration:	- even in high concentrations it does not cause decrease of livestock production or health deterioration of livestock,
	- it practically never reaches the explosive mixture concentration in stable.
5 Vol.%, CH_4	lower explosion limit (LEL) of methane.
17 Vol.%, CH_4	upper explosion limit (UEL) of methane.

Table 5. Biogas (methane CH_4+ carbon dioxide CO_2 + hydrogen sulphide H_2S = gas mixture)

Designation	Data, feature
Volume mass:	- biogas contains fundamentally three different gases (CO_2 and H_2S are heavier than air), - biogas is a mixture of different gases like methane, carbon dioxide, hydrogen and hydrogen sulphide, - the volume mass of biogas depends on the rate of contained gases.
Colour, odor:	- colourless (CH_4 and H_2S, CO_2), - odorless (CH_4 and CO_2), - odor of rotten egg (H_2S).
The lighter component of biogas (CH_4) is spread evenly in the ventilated air. The methane part of biogas and air can create an explosive mixture. The presence of biogas is clearly and in time recognizable about the odor of rotten egg in the breath of air.	
Main resources:	- the leaking biogas (e.g.. from the biogas pipeline),
	- the leaking biogas (e.g. from the fermentor).
Effects of accumulating biogas components to livestock and people:	- under sufficient concentration and duration the breathed biogas can cause poisoning death (because of hydrogen sulphide, H_2S) or suffocating death (because of carbon dioxide CO_2),
	- under sufficient concentration and duration the breathed (free from sulphure) biogas can cause suffocating death (because of carbon dioxide CO_2), - the breath in sweetened biogas can cause suffocating death (because of carbon-dioxide CO2) on account of lack of oxygen.
Biogas in air can explodes, if	- in the air and biogas mixture the rate of biogas is between 6-12%,
	- there is an ignition source with more than 700 ° C temperature.
Biogas in air can flames up, if	- in the air and biogas mixture the rate of the biogas is more than 12%,
	- there is an ignition source with more than 700 ° C temperature.

A CO_2 can be dangerous monitored by the oxygen concentration (decline or displacement of the CO_2 concentration). The ambient air contains 20% oxygen and 80% nitrogen. If the carbon dioxide concentration increases, oxygen and nitrogen are displaced by the carbon dioxide in a 4:1 ratio (Table 6.)

To decrease the oxygen concentration by 1%, the carbon dioxide concentration has to increase by 4%. Oxygen monitors activate the alarm at 17% volume. By this time, the carbon dioxide concentration has already reached a concentration leading to death.

The best confined space gas detector doesn't come from any one manufacturer; it's the instrument that best fulfills the requirements for your confined space program. Choosing the design that best fulfills the requirements for your specific program. Price should not be the sole determinant. Suggested criteria for instrument selection:

– sensor selection,
– sample-draw versus diffusion,
– classification for intrinsic safety,
– batteries,
– durability,
– datalogging versus non-datalogging,
– included accessories,
– warranty,
– operability,
– instrument performance specifications,
– alarms,
– calibration,
– evaluate before purchase.

The best instrument in the world is the one that's the best for your own individual conditions of use.

Table 6. Oxygen and nitrogen concentration in the ambient air according to increasing carbon dioxide concentration (Kleine, 2007).

Gas concentrations in the ambient air			
Carbon dioxide (**CO_2**) /Vol.-% /	Oxygen (**O_2**) /Vol.-% /	Nitrogen (**N_2**) /Vol.-% /	Effects of CO_2 to the people
0	20	80	no
4	19	77	headache, retching
8	18	74	leading to comas
12	17	71	comas
16	16	68	dead in seconds

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