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ENVIRONMENTAL IMPACT OF BIOGAS PLANT

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Abstract:
Biogas plants, through their work and energy production, contribute to reducing the emission of greenhouse gases, which is their biggest advantage. However, their benefit is also reflected in the disposal of waste from agricultural production and biodegradable municipal waste. But despite all the positive characteristics there are also negative ones. The negative impacts on the environment manifest in the emission of unpleasant odours and possible accident situations. Accidents are entirely related to improper management and maintenance of biogas plants with very low probability of occurrence. So, the risk of such situations cannot be ignored, but emphasis must be placed on the application of safety measures. In this paper will be analyzed the possible negative impact of the unpleasant odours, as well as the possible accident of an explosion at biogas plants.

Keywords*: biogas plant, negative impact, odour, explosion*

Introduction

In the context of rapid industrial development, environmental protection and sustainable resource management have become some of the most important global challenges. The increasing negative effect of the use of fossil fuels on the environment has led to intensive use of renewable energy sources.

Biogas plants represent an important component of renewable energy production, as they enable the simultaneous management of organic waste and generation of energy. Biogas is produced through the process of anaerobic digestion, in which microorganisms break down organic materials such as animal manure, agricultural residues, and biodegradable waste in the absence of oxygen. This process results in the production of biogas, primarily composed of methane and carbon

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dioxide, as well as digestate, a by-product that can be used as an organic fertilizer [1].

Despite their numerous environmental benefits biogas plants may also have certain negative impacts if not properly managed. These include potential methane leakage, water and soil contamination, and the emission of unpleasant odors.

The largest number of biogas plants in Serbia is located in Vojvodina and relies on the agricultural sector, animal husbandry, farming and food industry - which at the same time solve the problem of organic waste and reduce the greenhouse gas emissions. According to the data of the Serbian Electricity Company there are about 45 registered biogas plants, but the same number of such plants are under construction.

In 2023, there were over 21,322 biogas plants in Europe, with Germany, the UK, Italy, and France leading the way in total installed capacity, according to the European Biogas Association [2].

The aim of this paper is to analyze the negative impacts of biogas plants on the environment, with a particular focus on explosion and odours emmision and how to reduce treir risk of occurrence.

1. Explosion of biogas plants

Explosions represent one of the most serious safety and environmental risks associated with biogas plants. These incidents are primarily related to the presence of methane (CH_4), the main component of biogas, which is a highly flammable and explosive gas that can be mixed with air to form explosive premixes in containers or storage tanks [3].

Biogas typically contains 50–70% methane and 30–50% carbon dioxide, along with trace amounts of hydrogen sulfide, nitrogen, oxygen, ammonia and hydrogen may be present in small amounts as well. The explosion range of methane lies between 4 % and 17 % by volume in air [4,5,6]. Within this range, any ignition source, such as electrical sparks, open flames, static electricity, or overheating equipment, can trigger an explosion.

Further hazardous components of biogas are the asphyxiant carbon dioxide and the toxic hydrogen sulfide, which can be lethal even at low concentrations. The density of biogas is influenced by its carbon dioxide

content, the atmospheric pressure and temperature. The higher the concentration of carbon dioxide, the higher the density of biogas. If the composition of biogas is unknown, it has to be assumed that biogas can accumulate at the ceiling as well as in basements, pits, shafts and other cavities.

Explosions in biogas plants most commonly occur in enclosed or poorly ventilated spaces, such as digesters, gas storage tanks, pipelines, or engine rooms. Gas leaks caused by equipment failure, improper maintenance, or structural damage significantly increase the risk. In addition, the accumulation of hydrogen sulfide, although less flammable than methane, poses an additional hazard due to its toxicity and corrosive properties [2].

The consequences of explosions can be severe, including damage to infrastructure, release of hazardous substances into the environment, fires, and potential injuries or fatalities. Environmental impacts may involve air pollution from combustion gases, soil and water contamination due to leakage of digestate, and disruption of local ecosystems.

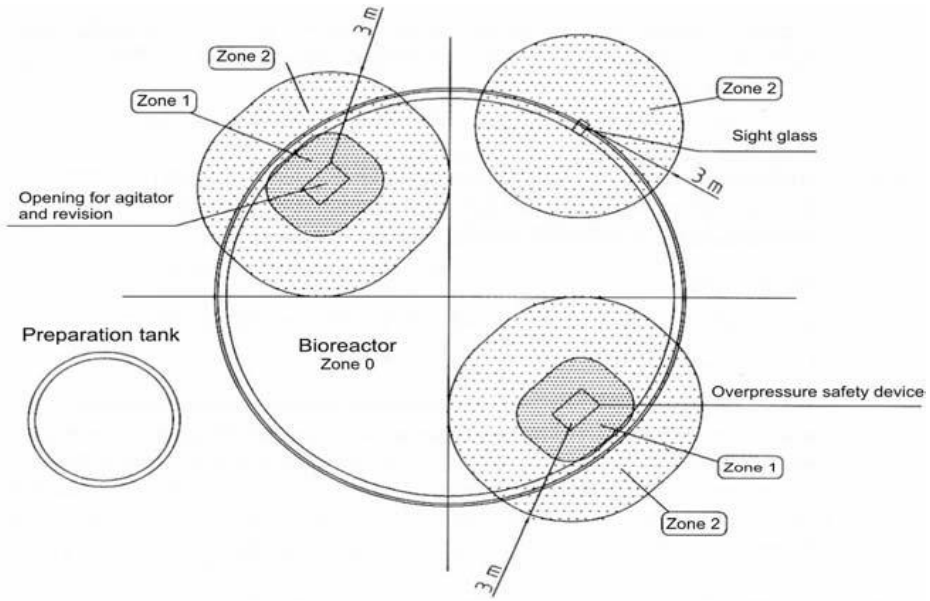
Areas with a potential risk of explosion are classified into Zones 0, 1, and 2 in accordance with the probability of occurrence of a hazardous explosive atmosphere. Zone 0 is defined as a space in which an explosive atmosphere—comprising a mixture of air with flammable gases, vapors, or mists—is present continuously, for prolonged periods, or with high frequency.

Zone 0 includes areas where explosive atmospheres are present continuously or for long periods, such as the gasholder, combustion engine air intake, and gas flare chamber. Under certain conditions, the bioreactor may also fall into this category if air ingress occurs. Normally, a slight positive pressure prevents air entry and ensures safe operation. Due to the presence of explosive mixtures, critical components must be isolated using safety devices such as flame arresters.

Zone 1 comprises areas where explosive atmospheres may occur occasionally. Under adequate ventilation, this zone typically extends up to 1 m from potential leakage points, such as equipment connections and service openings. Around exhaust outlets, safety devices, and in confined or poorly ventilated spaces, this distance may extend up to 4.5 m. Pits

and enclosed channels for anaerobic sludge are also included due to gas accumulation risks.

Zone 2 includes areas where explosive atmospheres are not expected under normal conditions, but may occur rarely and briefly. It typically extends 1–3 m from leak-tight components. Open pits, basins, and enclosed spaces with gas pipelines lacking ventilation are also classified as Zone 2, while fully enclosed spaces are generally assigned entirely to this zone [2].



Picture 1. *Vertical volume expansion of the Ex-zones* [7]

Hegazy et al. (2023) analyzes 75 occurrences of various types of accidents in biogas plants worldwide between 1990 and 2023. They concluded that explosions are the most common accident type, forming 69.3% of all occurrences. The primary causes of the analyzed accidents were ranked as follows: component failure, followed by maintenance errors, natural and technological disasters, equipment failure, operational errors, and, finally, the absence of personal protective equipment [2].

To minimize the risk of explosions, strict safety measures must be implemented. These include proper plant design with explosion-proof equipment, continuous monitoring of gas concentrations, regular inspection and maintenance of installations, and adequate ventilation systems. Additionally, the use of gas detection sensors and automatic shutdown systems can significantly reduce the likelihood of accidental ignition. Compliance with safety standards and regulations, such as those related to hazardous areas and explosive atmospheres, is essential for safe operation.

2. Odour emission from biogas plants

Odor emissions are a common environmental concern associated with biogas plants, particularly in facilities processing large amounts of organic waste such as animal manure, agricultural residues, and food waste. The main sources of the odour emissions from biogas station are transport and storage of materials, its manipulation, batching, quality of fermentation process, and storage, manipulation and transport of digestate [8].

The main compounds responsible for unpleasant odors include hydrogen sulfide (H_2S), ammonia (NH_3), volatile organic compounds (VOCs), and various sulfur-containing compounds such as mercaptans.

Odor intensity can vary depending on several factors, including the type of feedstock, operational conditions, temperature, and the efficiency of the digestion process. Inadequate sealing of digesters, leaks in gas handling systems, or improper storage of digestate can significantly increase odor emissions. Additionally, disturbances in the anaerobic digestion process such as overloading or imbalance in microbial activity, may lead to incomplete degradation of organic matter and the formation of odorous compounds [9].

Persistent odors may lead to public complaints, reduced acceptance of biogas projects, and potential regulatory issues. In some cases, exposure to higher concentrations of certain gases, such as hydrogen sulfide or ammonia, may pose health risks, including respiratory irritation and headaches.

Dynamic olfactometry represents the most widely applied sensory method for odour assessment, in which the human nose functions as the

primary detection instrument. This technique determines odour concentration by progressively diluting the sample gas with odour-free air until the detection threshold is reached. Odour concentration is thus expressed as the dilution factor required to achieve the olfactory threshold. The olfactory threshold is defined as the level of dilution at which the probability of odour detection under specified measurement conditions equals 0.5, meaning that 50% of a representative panel is able to perceive the odour. The threshold concentration is related to the odour unit (ou), which is defined as the amount of pollutant present in a cubic meter of air at the moment when the threshold is reached [10].

In our country, the standard for determination of odour concentration by dynamic olfactometry and odour emission rate (SRPS EN 13725:2022) was published on Sep 30, 2022. However, no accredited laboratory does this type of testing and so on, in our country, such tests are not done.

To mitigate odor emissions, several technical and operational measures can be implemented. These include the use of closed systems for feedstock handling, proper sealing of reactors and storage units, and the installation of air treatment technologies such as biofiltration, chemical scrubbing, and adsorption. Regular monitoring, maintenance, and optimization of the digestion process are also essential to prevent the formation and release of odorous compounds [11].

Biofilters typically consist of a fixed bed of porous media, such as wood chips or volcanic rock, through which contaminated air is passed. The porous medium provides a suitable environment for naturally occurring microorganisms that metabolize and degrade malodorous compounds present in the air stream.

Chemical scrubbing is another widely used technique for the removal of odorous compounds. In this process, contaminated air is brought into contact with a liquid phase that chemically reacts with the malodorous substances. Chemical scrubbers are commonly designed as vertical cylindrical columns in which the scrubbing liquid flows downward while the contaminated air moves upward. This method can be tailored to target a broad spectrum of odorous compounds and generally requires less installation space compared to biofiltration systems. However, it involves the use of chemical reagents and generates residual liquid streams that must be properly managed and disposed of.

Adsorption is an alternative odour control method that employs a fixed bed of adsorbent materials, most commonly activated carbon, through which the contaminated air is directed. The adsorbent medium captures and retains odorous compounds on its surface. Once the adsorption capacity is exhausted, the medium must either be regenerated through appropriate physicochemical processes or replaced. Adsorption systems are generally robust, adaptable to various types of odours, and compact in design relative to biofilters. Nevertheless, they require periodic replacement or regeneration of the adsorbent material, as well as proper handling and disposal of spent media [11].

3. Conclusion

Biogas plants play a significant role in sustainable energy production and waste management. However, their operation involves certain environmental and safety risks. Explosions represent the most critical hazard due to the presence of methane and the potential formation of explosive mixtures. The classification of hazardous areas, along with the application of appropriate safety measures, is essential for risk reduction.

Odour emissions are another important concern, primarily caused by compounds such as hydrogen sulfide, ammonia, and volatile organic compounds. Although not always directly harmful, they can negatively affect environmental quality and public acceptance. The implementation of closed systems, proper technology and treatment technologies of odour is therefore necessary.

In general, the negative impacts of biogas plants can be significantly reduced through proper design, operation, and adherence to safety and environmental standards, ensuring their sustainable and safe use.

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