Environmental impact assessment of municipal biogas plants – case study

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Abstract. Biogas plants processing the municipal waste are an important element of both municipal and energy management. Planned projects very often face objection from the public. The reluctance of people to accept this type of investment as a project potentially having a significant impact on the environment is caused by the fear of its nuisance. At the end of 2017, eight municipal biogas plants were operating in Poland. Before opening the biogas plants, residents were afraid of the related odours. The research involved the analysis of the occurrence of residents' complaints regarding the odour nuisance of municipal biogas plants to the authorities. Moreover, potential sources of anthrax associated with the operation of municipal biogas plants were identified. Based on the example of one of the plants, the applied deodorisation methods were presented, as well as the results of the odorimetric tests performed by an external laboratory. The paper presents positive ecological aspects of municipal biogas plants which apart from being a renewable energy source, are also important for reducing the amount of waste disposal.

1 Introduction

In the case of planned undertakings as well as those that will be subject to modernisation, the environmental impact assessment of the undertaking is of high importance. The environmental impact assessment (EIA) is a necessary tool of the identification, already at an early stage, of a potential threat for the environment and human life and health [1].

Biogas plants processing municipal waste constitute an important element of the technical infrastructure of cities, and therefore are of high importance for their sustainable development. The first undertakings of the type were implemented in Europe already in the 19th century [2]. Biogas is also currently obtained from different sources, i.e.: from waste dumps, biomass, sewage deposits, or municipal waste [3]. The largest biogas plants, with different processing power of approximately 57,000 Mg of waste, are located in France, and the smallest ones in Sweden – the annual processing power of approximately 10,000 Mg [4]. At the end of 2017, eight mechanical-biological installation for processing of municipal waste functioned, employing the fermentation process. One of its main objectives is obtaining energy from biogas. The processing powers of municipal biogas plants in Poland vary from 15,000 to approximately 30,000 Mg/year.

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Pursuant to the regulation on undertakings with potential significant environmental impact, biogas plants processing municipal waste are included to undertakings with potential environmental impact [5], which can be related to the necessity of preparation of an Environmental Impact Assessment (EIA). EIAs were prepared for all undertakings discussed in the paper located in Poland. They among others provide detailed characteristics of the undertakings, as well as point to potential threats for the environment and for human health and life.

2 Characteristics of operation of biogas plants processing municipal waste

Biogas plants where feedstock is composed of municipal waste are components of mechanical-biological installations for processing of municipal waste. Waste delivered to the plants is first supplied to the bunkers, and then moved to the mechanical part of the installation usually by means of a conveyor. At this stage, waste is subject to visual control for the purpose of identification of problem waste, i.e. waste that can interfere with further work of the devices. Then, the waste is sieved through a usually three-fraction sieve, and subject to processing in separators for the purpose of separating a possibly high amount of useful fractions from the stream of waste. The configuration of particular unitary operations, as well as the types of the applied devices are different in each plant. The waste collection system implemented in urban structures is of key importance for the operation of the installation.

The biological part of the installation is fed both waste subject to biodegradation collected selectively at the source, and the clarified fraction from the stream of mixed waste. The first stage of biological processing in the discussed plants is dry fermentation. This means that the content of dry mass in feedstock should vary from 20 to 40%. The second stage is oxygen stabilisation aimed at stabilising material in sanitary terms. Collection of the fraction of biodegradable waste at the source is the most recommended, because only their biological processing permits the production of compost as well as greater production of biogas also allowing for the production of a much higher amount of energy than in the case of the clarified biological fraction. The end product of waste processing separated from the stream of mixed waste is stabiliser constituting a new type of waste which usually is finally subject to landfilling [6]. In the case of processing of biodegradable waste from selective collection, the product can be compost that does not have a status of waste, and pursuant to the act on fertilisers and fertilisation [7] it can be applied as fertiliser or an agent supporting cultivation of plants. Moreover, only obtaining biogas from waste subject to biodegradation collected selectively is classified as a renewable energy source pursuant to the act on renewable energy sources [3].

3 Environmental impact of biogas plants processing municipal waste

In addition to advantages resulting from the recovery of waste (in the case of selectively collected waste subject to biodegradation), or its neutralisation (if the fraction from the stream of mixed waste is processed), as well as energy production installations of mechanical-biological processing of municipal waste, equipped with fermentation chambers together with the system of capturing biogas then used for energy engineering, also have a negative impact on the environment. Negative environmental impact of this type of undertakings includes emission of noise and pollutants, including odours. The interactions can also be felt as unpleasant by man [8].

3.1 Noise emission

Pursuant to the regulation of the Minister of the Environment of 14 June 2007 on admissible noise levels in the environment [9], in areas with multi-family housing development or homestead development, noise intensity by day should be lower than 55 dB(A) (from 6 to 22), whereas the reference time period is equivalent to subsequent eight least favourable days. By night (from 22 to 6), the noise intensity for the same type of building development should be lower than 45 dB(A), whereas the reference time period is equal to one least favourable hour in the night.

The primary sources of noise emission in biogas plants processing municipal waste include:

- car transport,
- loaders, often operating in open areas,
- grinders of green waste, operating periodically, and usually in open areas,
- technological halls with belt conveyors, a rotary sieve, grinders, waste segregation line, and round baler,
- concrete breakers,
- ventilators,
- extraction from the digestate dehydration station,
- biogas desulphurisation installation
- power generators,
- shredders,
- compactors on landfills (concerns plants with landfills) [10, 11].

The noise level from a given source is different for each plant, because it depends on the type of operating equipment, work conditions, and occurrence of sound absorbing barriers in the form of building development or trees, or other vegetation.

3.2 Emission of pollutants

Operation of plants of mechanical-biological processing of waste is related to the emission of different kinds of gases and dusts to the air. This paper particularly focuses on the odour impact of plants, resulting from the emission of pollutants in the form of odours.

The majority of unitary operations in waste management plants are related to the occurrence of odours. The intensity of the odour impact of the plants is determined by many factors related to the type and freshness of delivered waste, type of the applied technology, and proper performance of technological processes. The perception of odours is largely determined by meteorological conditions, i.e.:

- temperature and air humidity,
- wind speed and direction,
- occurrence of atmospheric precipitation.

Another condition determining the occurrence of the odour nuisance of objects is the distance of housing development from a given plant, as well as land relief.

Potential sources of odours in plants of mechanical-biological processing of waste particularly include:

- the place of delivery of waste in the premises of the plant,
- mechanical processing of waste,
- preparation of the feedstock for fermentation,
- dehydration of digestate,
- place of oxygen stabilisation of waste,
- shovelling of heaps of waste [12],

The primary compounds occurring in the process air include: hydrogen sulphide, ammonia, and volatile organic compounds (VOC) [13]. Odour thresholds (concentration causing the perception of the odour by 50% of persons in the representative group for a given population) for ammonia and hydrogen sulphide are as follows: 3.9 mg/m^3 (5.2 ppm), and 0.0123 mg/m^3 (0.0081 ppm) [14, 15]. It is difficult to identify the odour threshold for volatile organic compounds, because they are a mixture of different compounds.

3.1.1 Residents' complaints against the odour nuisance of plants

Table 1. presents the occurrence of residents' complaints against the odour nuisance of plants.

Table 1. Occurrence of residents' complaints against the odour nuisance of plants in the period from January 2015 to March 2018 (own elaboration based on data provided by state authorities).

Biogas Plant	**Authority**					
	Municipal/ Commune Office	Poviat Starost's Office	Voivodship Inspectorate of Environmental Protection	Regional Directorate of Environmenta l Protection	State Voivodship Sanitary Inspection	State Poviat Sanitary Inspection
Biała Podlaska	-	no data available	-	-	-	-
Promnik	-	-	no data available	+	no data available	-
Stalowa Wola	no data available	no data available	+	-	no data available	-
Jarocin	-	-	no data available	-	-	-
Tychy	-	no data available	no data available	no data available	+	+
Wólka Rokicka	+	-	-	-	no data available	-
Gać	-	-	-	-	no data available	-
Trzebania	-	no data available	-	-	no data available	-

Data in Table 1. suggest a moderate scale of the problem related to the odour nuisance pointed to by residents. The designation 'no data available' in the table suggests lack of information on the side of state authorities. The plus sign in the table means that a given authority recorded complaints against the operation of a given plant. The minus sign shows that no complaints occurred.

3.3 Waste Neutralisation Plant in Promnik – case study

The Waste Neutralisation Plant in Promnik (Strawczyn Commune) is equipped with an installation of mechanical-biological processing of municipal waste with processing power of more than 75 Mg/year. The installation is composed of:

– waste sorting line,
– biological waste processing station,
– composting station,
– high volume waste dissolution station,
– alternative fuel preparation station,
– building waste dismantling station,

– hazardous waste warehouse,
– warehouses and yards accompanying the objects,
– gas generators station.

The waste fraction with a diameter of 15-50 mm from mechanical processing in the installation, together with sewage deposits supplied from municipal wastewater treatment plants and green waste, is directed to the biological part. Its first stage is the methane fermentation process occurring in two fermentation chambers for a period of 21 days. Due to the content of dry mass of feedstock (approximately 30%) and temperature of the process (35°C), it is dry mesophilic fermentation.

After the fermentation process, the dehydrated sediment is subject to two-stage oxygen stabilisation: dynamic at a temperature of 40°C for a period of 30 days, and then static under a shed.

The fermentation process involves the operation of the following installations:
– preparation of feedstock for fermentation,
– post-fermentation waste dehydration station,
– sediment and sludge delivery point.

Feedstock for oxygen stabilisation in dynamic conditions is digestate dehydrated at the waste dehydration station, supplied by two lines (due to the variable morphology of waste for biological processing), or directly from sorting lines from the mechanical sorting hall with omission of fermentation processes [11].

3.3.1 Deodorising installation at the Waste Neutralisation Plant in Promnik

The mechanical waste processing hall, the process of fermentation and oxygen stabilisation in dynamic conditions, as well as unitary operations accompanying the processes are located in the so-called closed zone of the Plant. The zone is equipped with an air conditioning (decontamination) system. Air extracted from the intake passes through a ground pipe heat exchanger. The system cools the air in summer, and heats it in winter. All zones of the closed zone are supplied with air stream of 54.000 m^3/h. The air is subject to conditioning and photocatalysis processes for the purpose of elimination of hazardous substances and deodorants.

The dustiness of the closed zone is minimised through misting. The air stream is largely used up in the zone of biological processing of waste. Then, it is directed to the chemical scrubber with sulphuric acid for the reduction of the concentration of volatile organic compounds (VOC) and misting, and then to the oxybiofilter located outside the building. The oxybiofilter is a device where used air passes through a layer of glass where sulphuric acid precipitates, aluminium fulfilling the expansion function, and a layer of bark with filtering properties. Between the chemical scrubber and oxybiofilter, in the ventilation duct, ozonisation and photocatalytic oxygenation occurs by means of titanium oxide(IV) (TiO_2).

The combination of two reagents, i.e.: ozone O_3 and catalytic ions TiO_2 is a very beneficial solution. The addition of ozone almost doubles the amount of catalytic ions, i.e.: radicals of OH*, hydrogen peroxide, active oxygen O_2*, and others. Moreover, ozone protects the catalytic surface from crystallisation of some organic compounds, and ensures the reduction of methane (CH_4), the remaining ammonia (NH_3), strong reduction of hydrogen sulphide (H_2S), and other inorganic deodorants, among others methyl mercaptan.

Catalytic ions together with ozone provide for the reduction of volatile organic compounds (VOC) and organic deodorants. Moreover, all kinds of bacteria, fungi, or moulds still present in the output air in spite of passing through the acid scrubber are subject to reduction [11].

3.3.2 Results of odorimetric research

In April 2017, olfactometric analyses were performed in the premises of the Plant by an external laboratory. The research was conducted in seven points. Five of them were external ventilators from the mechanical waste segregation hall, and two further ones were points representative of the Plant in terms of occurrence of odours, i.e.: waste delivery and storage hall and manual segregation hall. In each of the points, three air samples were collected into bags made of materials meeting the norm PN-EN 13725 [16]. Results of the measurements are presented in Table 2. During the collection of samples for olfactometric research, air temperature varied from 16.9 to 17.0°C, relative air humidity from 48.9 to 55.4%, and wind speed 2.2-2.8 m/s (wind direction: south-eastern).

Table 2. Results of olfactometric research of 25.04.2018 (Own elaboration based on data provided by the Waster Neutralisation Plant in Promnik).

Measurement point		**Odour concentration [ou/m^3]**		
		Sample 1	**Sample 2**	**Sample 3**
Waste delivery and storage hall		117	71	139
		Mean value: 109.00		
Mechanical segregation hall	W1	124	99	155
		Mean value: 126.00		
	W2	99	63	139
		Mean value: 100.3		
	W3	35	89	47
		Mean value: 57.00		
	W4	31	99	147
		Mean value: 92.33		
	W5	401	706	535
		Mean value: 547.33		
Manual segregation hall		30	31	26
		Mean value: 29.00		

Data included in Table 2. suggest that the highest odour concentration occurs in point W5, constituting a part of the mechanical waste segregation hall. The mean value of measurements performed for the point is 547.33 ou/m^3. The hall is automated. Employees are not exposed to work in a place with high concentration of odours in the air which could be strenuous, or even dangerous for their health. In the place of constant presence of employees, i.e. in the manual segregation hall, the odour concentration is considerably lower, and averages 29 ou/m^3.

The analyses should be repeated, preferably in an annual cycle, to permit the analysis of the impact of meteorological conditions and variability of the morphological composition of delivered waste on the phenomenon of odours. Literature data [13] suggests that the primary odorants in waste management plants include: ammonia, hydrogen sulphide, and volatile organic compounds. It would also be worthwhile expanding the research by measurements of concentrations of the aforementioned compounds which can be harmful for human health and life.

4 Summary and conclusions

Biogas plants processing municipal waste bring vast benefits both for the municipal and energy engineering management, but also for sustainable development. The plants can be included to renewable energy sources, but only when the feedstock is composed of biodegradable, selectively collected waste. This measure is also stipulated by the national plan for waste management by 2022 [17]. It stipulates the transformation of plants of mechanical-biological waste processing in the mechanical part into post-cleaning installations for municipal waste from selective collection, and in the biological part into a source of production of compost meeting requirements for fertilisers and crop production products [7].

Negative aspects of biogas plants certainly include noise and odour emission. The impact does not have to affect the quality of life of residents, es evidenced by the performed analysis of occurrence of residents' complaints against odour nuisance. In the case of the Waste Neutralisation Plant in Promnik, complaints to the Regional Directorate of Environmental Protection came from residents of the Piekoszów Commune. It is worth emphasising that in the Piekoszów municipality (Piekoszów Commune) neighbouring on the Strawczyn Commune, an agricultural biogas plant operates. Therefore, only detailed odorimetric research would identify which biogas plant constitutes the source of odour nuisance.

The olfactometric analyses performed by an external laboratory at the Plant in Promnik identified the place of the highest odour concentration – ventilator No. 5, extracting process air from the hall of mechanical sorting of waste. The lowest odour concentration was observed in the place of work of people.

The paper evidences that the application of proper deodorisation can considerably reduce both odour concentration and the concentration of some pollutants occurring in the air as a result of processes occurring in the installation. Maximum hermitization of particular technological processes and discipline of employees operating the installation are very important aspects in the case of minimising the odour and noise impact.

The expansion of olfactometric analyses by other points, i.e. hall of oxygen stabilisation in dynamic conditions and yard of oxygen stabilisation in static conditions, as well as performance of the analyses in an annual cycle would permit a detailed description of the odour impact of the Plant in Promnik. The determination of the concentration of hydrogen sulphide, ammonia, and volatile organic compounds, constituting the primary odorants in waste processing plants, would also be important for odorimetric research.

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