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Assessment of the Possibility of Introducing a Cogeneration System in the Biogas Development Process by the Example of the Wastewater Treatment Plant Located in Rybnik Orzepowice

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1. Introduction

Combined electricity and heat production systems are used in sewage treatment plants due to the possibility of using heat to warm up the sludge which has been introduced and circulates in separate fermentation chambers (Polish acronym: WKF) and the use of electricity for the plant's own purposes or for sale to external customers (Kołodziejak 2012). Biogas cogeneration systems are used to produce combined electricity and heat in wastewater treatment plants. Biogas is a product derived from the sludge fermentation process carried out in fermentation chambers. In accordance to Art.2 point 28 Directive (EU) 2018/2001 biogas means "gaseous fuels produced from biomass" (Directive 2018/2001).

Biogas consists mainly of methane: 55-70%, carbon dioxide: 32-37%, hydrogen: about 1%, nitrogen: 0.2-0.4% and other gases in trace amounts (e.g. Słupek 2020, Kisielewska 2020). In biogas, hydrogen sulphide is also found in trace amounts, which due to corrosive aggressiveness is removed from the tank prior to biogas storage in it (Oleszkiewicz 1998).

Table 1 summarizes the results of biogas testing from the Rybnik Orzepowice wastewater treatment plant carried out in the years 2015-2018.

Information in the scientific literature provided by many authors indicates that in very favourable conditions it is possible to obtain 200 m^3 of biogas from 1,000 m^3 flowing into municipal sewage treatment plants. However, when calculating the technical potential it is assumed that 100 m^3 of biogas can be obtained from 1000 m^3 of sewage flowing in (Kaltschmitt 2001).

According to (Kołodziejak 2012), on average, one cubic meter of biogas allows the production of:

- for a split system:
  - 2.1 kWh of electricity (assuming 33% system efficiency),
  - 5.4 kWh of thermal energy (assuming 85% system efficiency),
- for the combined system: 2.1 kWh of electricity and 2.9 kWh of heat.

Table 1. Results of biogas tests carried out from 2015-2018

Parameter	Unit	Date of the analysis				Arithmetic mean
		2015-02-13	2016-03-21	2017-03-24	2018-03-26	
Methane CH_4	% vol.	60.90	63.00	69.90	65.90	64.93
Carbon dioxide CO_2	% vol.	38.90	37.00	30.10	34.10	35.03
Oxygen O_2	% vol.	<0.1	<0.1	<0.1	<0.1	<0.1
Carbon monoxide CO	% vol.	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nitrogen N_2	% vol.	<0.1	<0.1	<0.1	<0.1	<0.1
Hydrogen sulphide H_2S	ppm	9.0	41.0	35.0	6.0	22.75
Calorific value	kJ/m^3	21,860.0	22,600.0	25,100.0	23,655.0	23,303.8

Source: (Karwot et al. 2018)

Variable atmospheric conditions affecting fluctuations in the wastewater inflow, i.e. precipitation, drought, temperature affect the amount of biogas produced and the demand for heat and electricity in the wastewater treatment installation.

2. Research methodology

2.1. Research object

The Rybnik-Orzepowice wastewater treatment plant which operates in the Biodenipho® technology (Karwot et al. 2018) is located in Rybnik. It receives and treats wastewater from Rybnik agglomeration with a pollutant load expressed as Equivalent Number of Residents of about 92,000 PE (Person Equivalent). In addition to the mechanical-biological-chemical processes of wastewater treatment, the sewage treatment plant has a sludge processing node, including a part related to sewage sludge fermentation, biogas storage and processing.

The biogas storage and processing installation includes the following devices:

- biogas desulphurisation tank,
- condensate wells (2 pcs),
- biogas tank,
- biogas blower,
- biogas analyser,
- cogeneration unit,
- gas boilers,
- flare.

A cogeneration unit and gas boilers generate energy in the form of electricity and heat. Electricity from a cogeneration unit is used for the sewage plant's own needs or it is sold to an external recipient. The generated heat, however, produced on the cogeneration unit and in boilers is used to maintain the temperature of the sludge in the methane fermentation process, to heat buildings and to prepare domestic hot water.

The following has been installed in the system:

- two Viesman VITOPLEX 350 boilers with a rated heat output of 350 kW, each,
- PETRA 250C cogenerator with an electric rated power: 190/190 kVA/kWe, rated thermal power 231 kW, with electrical efficiency: 38.6%, thermal efficiency: 46.9%.

The cogenerator operates with a power of approx. 180 kWe (i.e. with an efficiency of approx. 94.7%), which allows obtaining around 4,320 kWh/d per day. With the maximum use of the power of a cogeneration unit, approx. 4,560 kWh/d of electricity can be obtained daily. Operation at maximum power is not recommended by the device manufacturer. During operation, oil change intervals occur (every 400 hours of operation) and the machine is serviced (every 1,600 hours of operation). Due to the synchronization of the electricity generated from the cogenerator, with the electricity from the external operator, there are also periodic breaks in the operation of the cogeneration system.

The total rated thermal power of the devices is 931 kW, including: 700 kW boiler power (two 350 kW boilers), 231 kW cogeneration power. The heat production system is not metered. Biogas is the main fuel used to produce electricity and heat, but it is possible to supply boilers with natural gas.

In summer, the sludge is heated mainly with the heat from the cogenerator. In winter, half of the heat required to heat the sludge comes from a cogenerator, while the rest from boilers. The heat from boilers is used in winter to heat the administrative buildings and workshop buildings. In the case of insufficient amount of biogas, boilers can also be supplied with natural gas.

2.2. Research methodology

Measurement data of the years 2013-2018 (daily, monthly data) held by the Water and Sewage Limited Liability Company [Przedsiębiorstwo Wodociągów i Kanalizacji Sp. z o.o.] in the scope of: the amount of inflowing sewage, the amount of biogas produced and consumed by the cogeneration unit, boilers and biogas sent to flaring, the amount of electricity generated from biogas, the total amount of electricity consumed by the Rybnik-Orzepowice sewage treatment plants.

The monthly amounts of wastewater flowing into the treatment plant were determined on the basis of measurements of the daily wastewater inflow. The amount of wastewater flowing through the Sewage Treatment Plant in Rybnik-Orzepowice is measured continuously with an ultrasonic level meter installed in a measuring chamber with a Parschall venturi, measuring 16.7x2.48 m, located behind the main pumping station. Table 2 presents the average daily sewage flow in the years 2013-2018 broken down by months. Table 3 presents the average daily amount of biogas produced in the years 2013-2018 divided into months.

Biogas flow is measured separately on each device, i.e. biogas flow directed to boilers: MZ 50 turbine flow meter manufactured by Itron (Q_{max} = 100 m^3/h, Q_{min} = 6 m^3/h, 1 ipuls = 0,1m^3), gas flow to the cogeneration unit: turbine flow meter MZ 80 manufactured by Itron (Q_{max} = 160 m^3/h, Q_{min} = 10 m^3/h, 1 ipuls = 1 m^3), biogas flow to the flare: MZ 100 turbine flow meter manufactured by Itron (Q_{max} = 400 m^3/h, Q_{min} = 16 m^3/h, 1 ipuls = 1 m^3).

The wastewater treatment plant in Rybnik is powered by two 20 kV cable lines at the ends of which there are 20/0.4 kV transformers. Each transformer supplies the main switchboard: RG1 and RG2 with a voltage of 0.4 kV, which work separately. A coupling was located between the RG1 and RG2 switching stations. The electricity produced in cogeneration is sent exclusively to the RG2 switching station and mostly used for own needs. The excess of electricity produced in cogeneration is sent to the power network. Based on the indications of the metering and billing system installed on the 20 kV line and the generator's gross production measurement system, the amount of electricity from cogeneration used for own needs is calculated.

Table 4 presents the average daily total demand for electricity by wastewater treatment plant Rybnik-Orzepowice (WWTP Rybnik-Orzepowice) in the years 2013-2018 broken down by months. Table 5 shows the average daily amount of electricity produced from biogas by WWTP Rybnik-Orzepowice in 2013-2018, broken down by month.

Table 2. Average daily sewage flow in 2013-2018 broken down by months [m^3/d]

Year	Month												Annual mean
	01	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**	**12**	
2013	16,898	18,944	18,109	20,035	23,241	26,665	17,579	16,227	18,792	15,504	16,054	15,946	**18,666**
2014	15,557	16,324	16,773	15,981	17,907	19,067	17,965	19,746	21,794	18,271	18,017	17,403	**17,900**
2015	17,321	17,487	16,915	16,236	16,577	16,858	15,697	14,297	15,088	15,328	17,018	16,319	**16,262**
2016	16,680	18,494	16,872	17,930	15,912	17,274	19,219	18,541	16,109	18,234	16,605	18,187	**17,505**
2017	16,530	19,316	18,765	22,307	20,133	18,489	18,299	17,334	22,010	23,609	20,897	19,911	**19,800**
2018	17,702	17,356	18,706	17,174	19,227	19,592	17,766	16,097	16,300	16,608	15,322	17,866	**17,476**
Mean	***16,781***	***17,987***	***17,690***	***18,277***	***18,833***	***19,658***	***17,754***	***17,040***	***18,349***	***17,926***	***17,319***	***17,605***	***17,935***

Source: own elaboration

Table 3. Average daily biogas quantity of biogas produced in 2013-2018 broken down by month [m^3/d]

Year	Month												Annual mean
	01	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**	**12**	
2013	3,150	2,990	3,003	3,311	3,591	3,430	2,914	2,546	2,755	2,933	2,796	3,144	**3,047**
2014	3,027	2,996	3,345	3,661	3,734	3,558	3,164	2,636	2,538	2,591	2,805	3,164	**3,102**
2015	3,317	3,204	3,069	3,260	3,166	2,485	2,609	2,238	2,049	2,328	2,688	3,051	**2,789**
2016	2,804	2,983	2,824	2,831	2,756	2,525	2,323	2,610	2,778	2,342	2,176	1,860	**2,568**
2017	1,907	2,822	2,968	2,863	2,906	2,420	2,098	1,907	2,062	2,297	2,855	2,746	**2,488**
2018	3,037	2,630	2,685	3,018	2,805	2,971	2,897	2,666	2,539	2,529	2,974	3,622	**2,864**
Mean	**2,874**	**2,938**	**2,982**	**3,157**	**3,160**	**2,898**	**2,668**	**2,434**	**2,454**	**2,503**	**2,716**	**2,931**	**2,809**

Source: own elaboration

Table 4. Average daily total electricity demand by the OS Rybnik-Orzepowice in 2013-2018 broken down by month [kWh/d]

Year	Month												Annual mean
	01	02	03	04	05	06	07	08	09	10	11	12	
2013	8,946	9,176	9,633	9,360	9,206	9,128	7,917	8,245	8,295	7,955	8,171	9,047	**8,757**
2014	8,727	9,271	8,905	8,438	7,964	7,929	7,834	8,126	8,885	8,650	9,015	9,217	**8,580**
2015	8,918	8,799	9,079	9,018	8,730	9,709	8,220	8,463	9,354	9,554	9,261	8,599	**8,975**
2016	8,993	8,534	8,810	8,716	8,354	8,178	8,005	7,867	7,621	7,788	8,143	8,776	**8,315**
2017	9,635	9,637	9,535	9,987	9,136	9,070	8,526	8,468	8,832	8,943	9,103	9,759	**9,219**
2018	9,483	9,626	10,667	10,178	9,235	8,896	8,311	8,388	8,383	8,886	8,990	9,686	**9,227**
Mean	**9,117**	**9,174**	**9,438**	**9,283**	**8,771**	**8,818**	**8,135**	**8,259**	**8,562**	**8,629**	**8,780**	**9,181**	**8,846**

Source: own elaboration

Table 5. Average daily amount of electricity produced from biogas by WWTP Rybnik-Orzepowice in 2013-2018 broken down by month [kWh/d]

Year	Month												Annual mean
	01	02	03	04	05	06	07	08	09	10	11	12	
2013	3,489	4,287	4,146	4,182	4,053	3,724	4,286	4,094	3,923	4,145	4,245	4,247	**4,068**
2014	4,005	4,253	4,123	3,832	4,013	3,454	4,059	3,996	4,044	4,110	3,997	3,970	**3,988**
2015	4,237	4,184	4,256	4,194	4,057	2,566	3,894	3,952	3,496	3,930	3,905	3,603	**3,856**
2016	3,890	3,573	3,855	3,653	3,788	4,146	4,158	4,202	4,149	2,657	2,447	2,512	**3,586**
2017	2,387	3,200	4,220	4,251	3,984	4,158	3,896	3,612	3,756	3,861	3,916	4,221	**3,788**
2018	3,489	4,287	4,146	4,182	4,053	3,724	4,286	4,094	3,923	4,145	4,245	4,247	**4,068**
Mean	**3,583**	**3,964**	**4,124**	**4,049**	**3,991**	**3,628**	**4,096**	**3,992**	**3,882**	**3,808**	**3,793**	**3,800**	**3,892**

Source: own elaboration

3. Results and their interpretation

Analysing the average value of sewage inflow for 2013-2018, it can be stated that it remains at the level of 17,935 m^3/d (dry periods: -20.2%; periods with precipitation: + 48.7%). Significant fluctuations in the amount of sewage inflow are associated with the extensive sewage network, which in some parts is combined sewage system. In the months May-June and September-November, increased sewage inflows to sewage treatment plants are observed, resulting from the occurrence of increased precipitation in these months. Daily variability of wastewater inflow is presented in Figure 1.

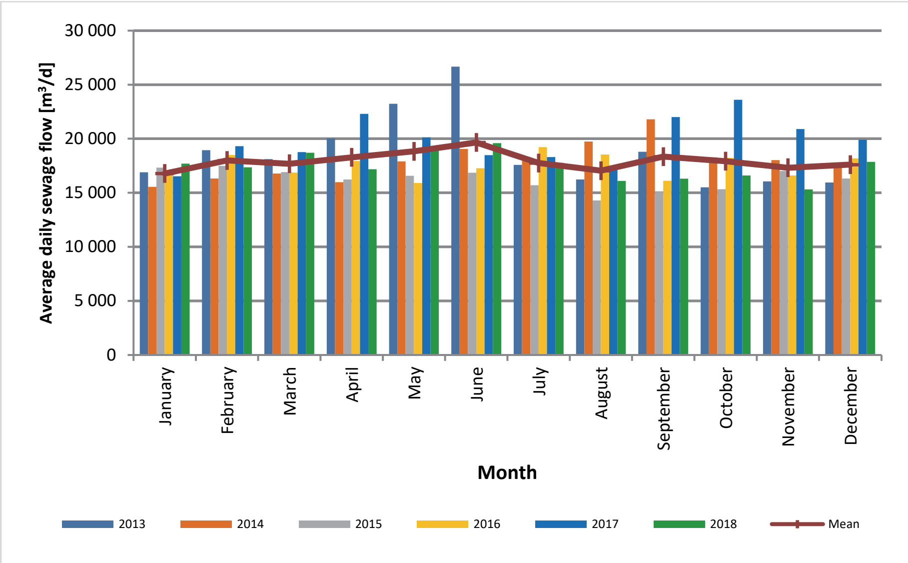

Fig. 1. Average daily sewage flow in 2013-2018 broken down by month [m^3/d]; Source: own elaboration

Analysing the average value of biogas production for 2013-2018, it can be stated that it remains at the level of 2,809 m^3/d (±33%). A decrease in biogas production is observed in the months June-October. The average daily amount of biogas produced in 2013-2018 is presented in Figure 2.

Analysing the average value of total electricity consumption for 2013-2018, it can be stated that it remains at the level of 8,846 kWh/d (-13.8%; +20.6%). Reduced demand for electricity occurs in the summer months (July-September), while in the autumn-winter-spring period there is a higher electricity consumption compared to the average. The average daily total demand for electricity is shown in Figure 3.

Analysing the average value of electricity generated from biogas for 2013-2018, it can be stated that it remains at the level of 3,892 kWh/d (-38.7%; +10.1%). Chart 4 presents the average daily amount of electricity produced from biogas by WWTP Rybnik-Orzepowice in 2013-2018 broken down by month.

Analysing long-term data on the amount of electricity produced from biogas in relation to the total demand for electricity by the treatment plant, it can be concluded that the energy produced from biogas allows us to cover the demand at the level of 44% (minimum 39%, maximum 50%). Chart 5 presents the share of electricity generated from biogas in relation to the total demand for electricity by the treatment plant.

Biogas consumption in 2013-2018 by individual facilities amounted to: cogeneration unit approx. 65%, boilers: 10%, flare: 25%. More than 75% of biogas is used to produce electricity and heat used for the sewage plant's own needs. Excess biogas, i.e. about 25% is burned in a flare.

Figure 6 shows the use of biogas in the system: cogeneration unit, boilers and a flare. The data shows the work of the above units in the years 2013-2018 and are average daily monthly values.

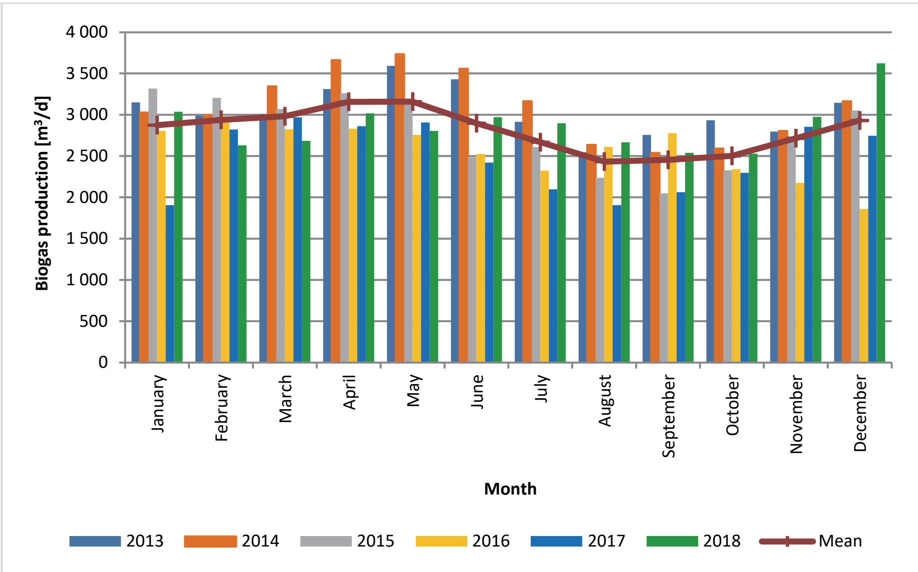

Fig. 2. Average daily biogas quantity of biogas produced in 2013-2018 broken down by month [m^3/d]; Source: own elaboration

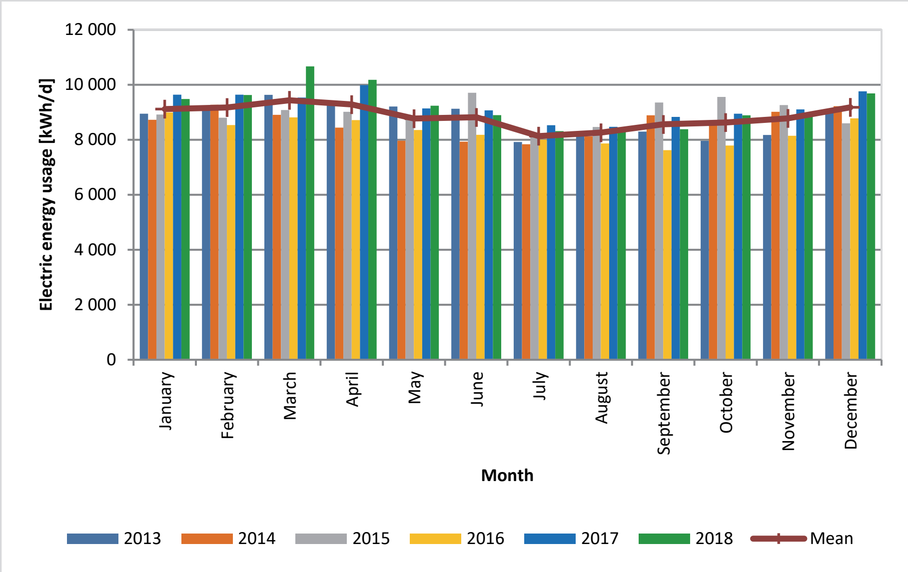

Fig. 3. Average daily total demand for electricity by WWTP Rybnik-Orzepowice in 2013-2018 broken down by month [kWh/d]; Source: own elaboration

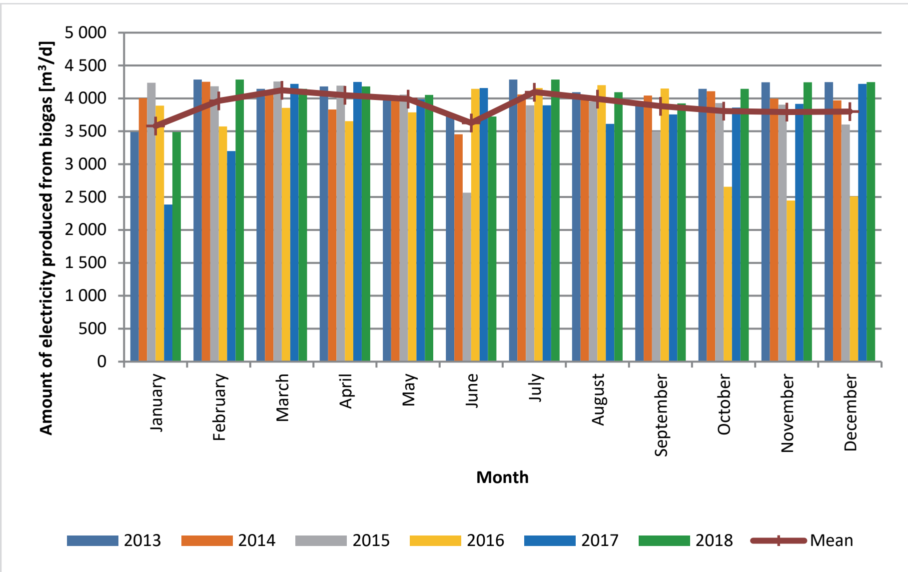

Fig. 4. Average daily amount of electricity produced from biogas by WWTP Rybnik-Orzepowice in 2013-2018 broken down by month [kWh/d]; Source: own elaboration

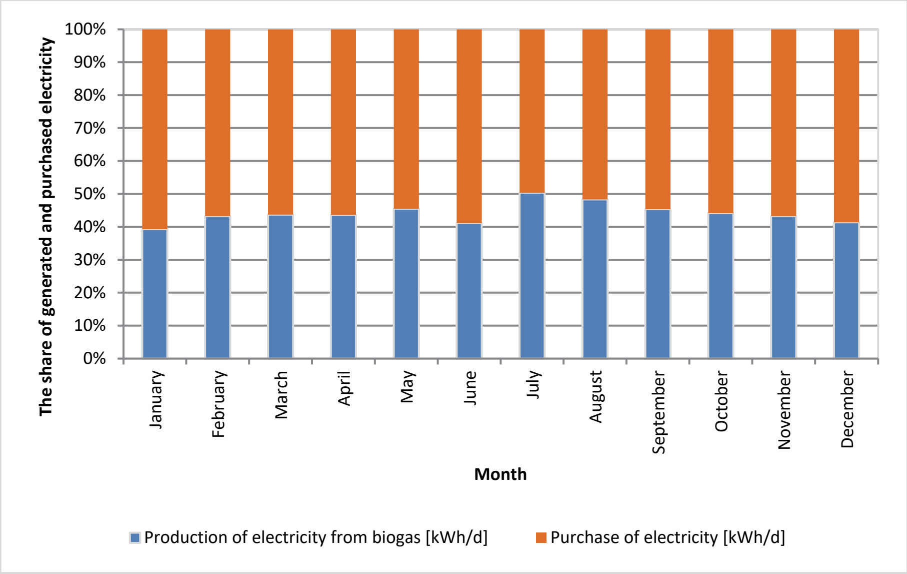

Fig. 5. The share of electricity generated from biogas in relation to the total demand for electricity by the treatment plant; Source: own elaboration

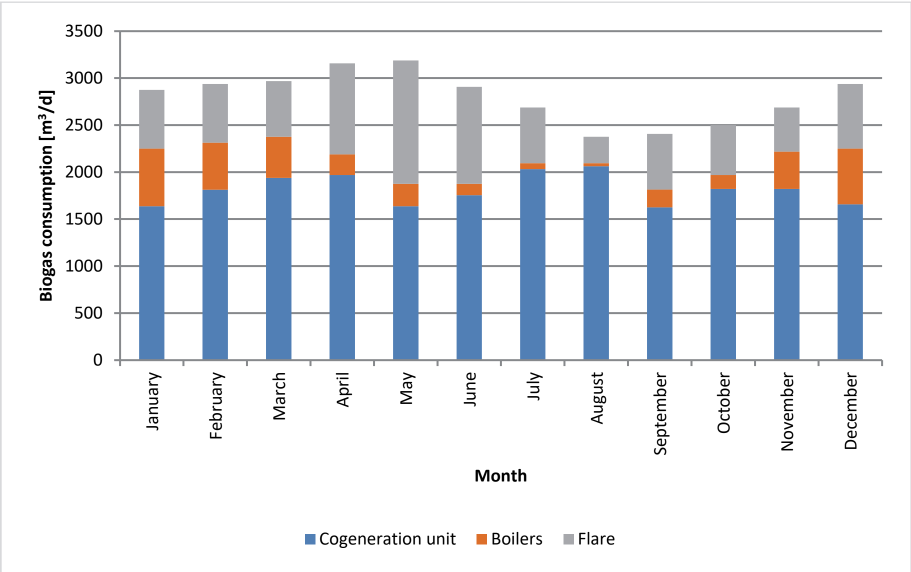

Fig. 6. The use of biogas in the system: cogeneration unit, boilers and flare; Source: own elaboration

In Kaltschmitt & Hartmann (2001) is presented assumptions for a cogeneration installation converting biogas into electricity and heat. The installation was planned for biogas combustion in the amount of 2115 m_n^3/d, with an estimated biogas extraction rate from sewage at the level of 0.101 m_n^3/m^3 (Energoprojekt Gliwice 2009). The monitoring of the daily amount of sewage inflow and the daily amount of biogas produced showed that during 6 years of operation of the installation, the average daily amount of biogas produced was 2809 m_n^3/d (min. 1806 m_n^3/d, max. 3102 m_n^3/d). In relation to the assumed amount (Energoprojekt Gliwice 2009, Smyk et al. 2017), in real operating conditions the amount of biogas increased by approx. 38.2%. The increase in the amount of biogas is closely related to the unit index of obtaining biogas from wastewater, whose average value from the years 2013-2018 amounted to 0.1584 m_n^3/m^3 (min. 0.0937 m_n^3/m^3, max.: 0.2291 m_n^3/m^3). The unit index of obtaining biogas from sewage calculated on the basis of data from six years of operation is by 56.8% higher than the adopted value (Energoprojekt Gliwice 2009, Smyk et al. 2017).

Figure 7 presents changes in the unit indicator of biogas extraction from sewage per month in the years 2013-2018.

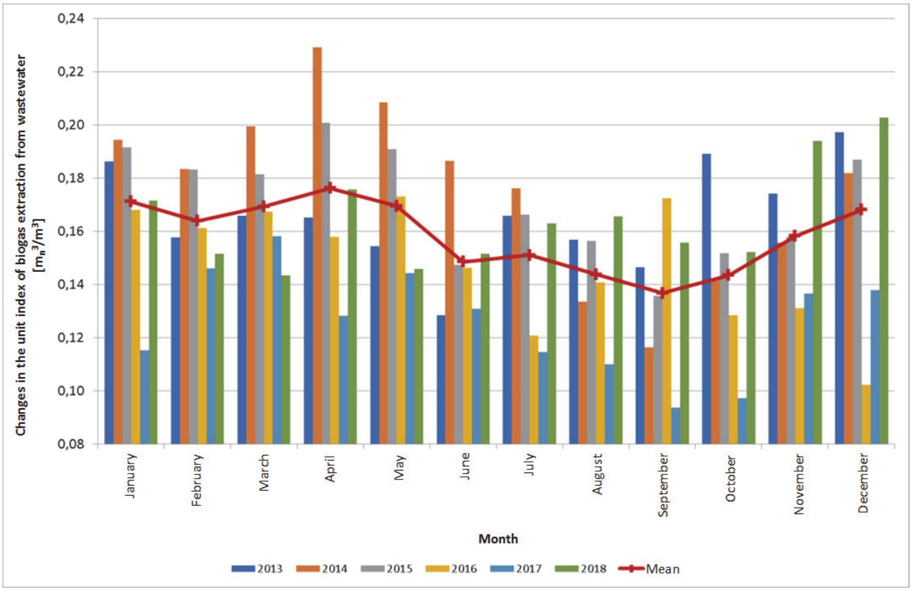

Fig. 7. Changes in the unit index of biogas extraction from wastewater per month in the years 2013-2018; Source: own elaboration

The lowest average annual value of the unit index of biogas extraction from wastewater was recorded in 2016 and it was 0.1475 m_n^3/m^3. It was lower than the average value from many years by about 7.3%. The highest value was recorded in 2014 and amounted to 0.1756 m_n^3/m^3. It was higher than the value from many years by about 10.8%.

The unit amount of biogas in relation to the COD (Chemical Oxygen Demand) load, according to research (Banks et al. 2011, Wilderer 2011) is estimated at 0.35 m^3 biogas/kg COD. Analysis of data from many years in the case of WWTP Rybnik-Orzepowice showed that on average 0.22 m^3 of biogas/kg COD can be obtained in the case of inflowing sewage.

Fig. 8 presents the unit amounts of biogas in relation to the pollution load expressed as COD, in the years 2013-2018, on a monthly, average daily basis.

The highest unit amount of biogas in relation to the COD load in the incoming sewage was 0.47 m^3 of biogas/kg COD, while the lowest was 0.09 m^3 of biogas/kg COD. Unit low values of the amount of biogas in relation to the COD load are recorded in months with increased sewage inflow to the treatment plant, while high – in months with medium and low flows.

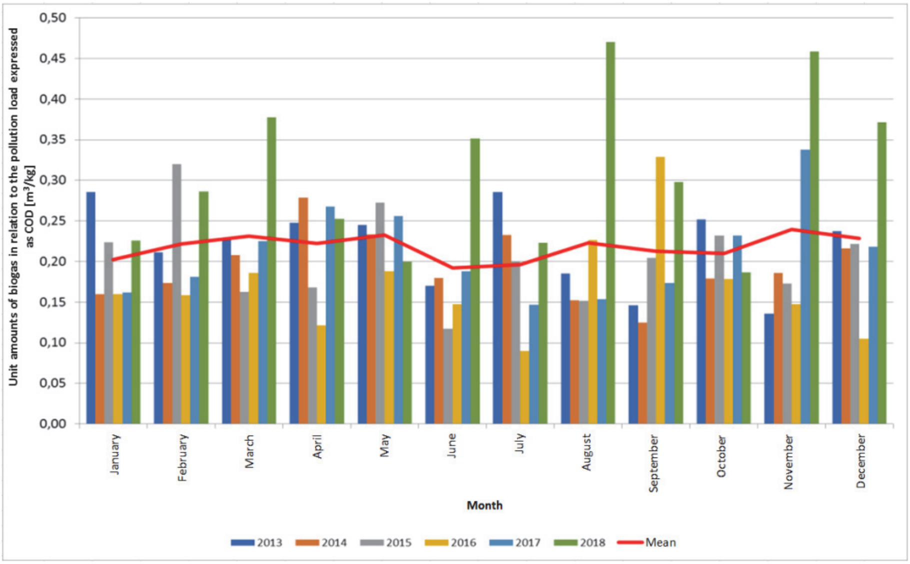

Fig. 8. Unit amounts of biogas in relation to the pollution load expressed as COD, in 2013-2018, on a monthy, average daily basis; Source: own elaboration

The unit amount of biogas in relation to the BZT_5 (Biochemical Oxygen Demand) load, according to research (Wilderer 2011) is estimated at 0.4-0.98 m^3 of biogas/kg BZT_5. The maximum amounts of biogas in relation to the BZT_5 load were obtained at the level of 1.46 m^3 biogas/kg BZT_5 at a ratio of pollutants BZT_5/COD = 0.5 (Wilderer 2011). Analysis of data from many years in the case of WWTP Rybnik-Orzepowice showed that on average 0.61 m^3 of biogas/kg BZT_5 can be obtained in the case of inflowing sewage.

The highest unit amount of biogas in relation to the BZT_5 load in the incoming sewage was 1.20 m^3 biogas/kg BZT_5, while the lowest was 0.28 m^3 biogas/kg BZT_5. Figure 9 presents the unit amounts of biogas in relation to the pollution load expressed as BZT_5, in the years 2013-2018, on a monthly, average daily basis.

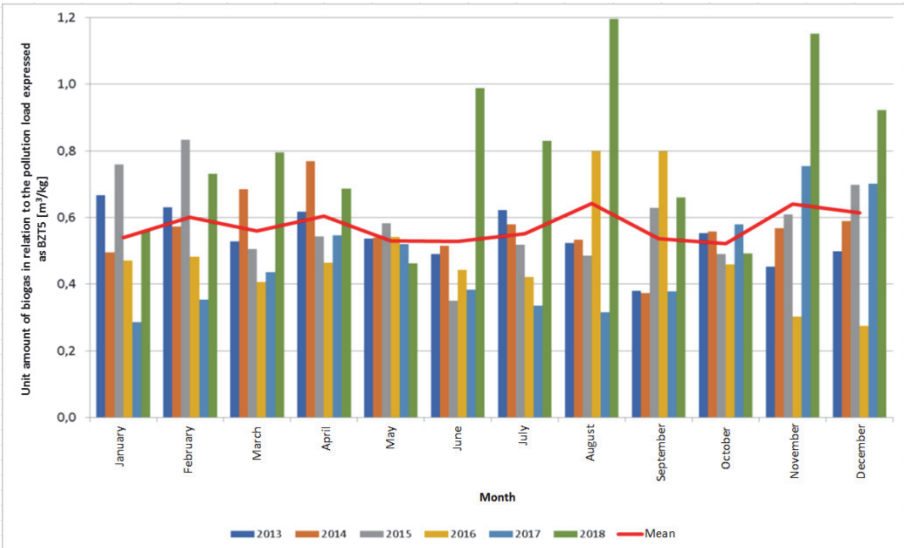

Fig. 9. Unit amount of biogas in relation to the pollution load expressed as BZT_5, in the years 2013-2018, on a monthly basis; Source: own elaboration

The unit amount of biogas obtained from the COD and BZT_5 load is closely correlated, from data from many years, the BZT_5/COD pollution ratio is 0.39, which indicates the inflow of sewage with hardly decomposable compounds (Smyk et al. 2017, Zdebik et al. 2010).

4. Conclusions

Based on the results of own research, obtained in operating conditions after the construction of the cogeneration system, i.e. in a 6-year period, it can be stated that:

- The value of the unit index of biogas extraction in relation to the amount of sewage, changes and depends on the inflow of sewage and the load of pollutants contained in it. The parameters and conditions of the fermentation process (e.g. temperature, amount of excess and initial sludge introduced, age of sludge in the fermentation chamber, etc.) are also significant,
- In the annual operation cycle of the sewage treatment plant, a reduction in biogas production is observed in the months June-October, which is influenced by the load of pollutants inflowing with sewage.
- In winter, biogas is 85% combusted in a cogeneration unit and boilers, and the heat obtained is used 100% to heat sludge and buildings. The generated electricity covers 44-47% of the total balance of the treatment plant. The remaining amount is burned in the flare.
- In summer, biogas is burned mainly in a cogeneration unit and in a flare. The heat obtained in the cogenerator is 100% sufficient to heat the sludge in the fermentation chamber system. In periods with lower temperature, the sludge is additionally heated with heat from biogas combustion in boilers.
- The electricity produced in the cogeneration unit in the summer covers 45-50% of the total electricity consumption of the treatment plant. The amount of biogas burned in the summer in the cogeneration unit is at the level of 75%, the remaining amount is burned in the flare. Increasing the amount of electricity from biogas combustion in the existing technological system will result in excess heat, which will be difficult to manage in summer.
- The maintenance of sludge concentration in biological chambers in summer and winter is directly related to the amount of excess sludge discharged into the methane fermentation chambers. This results in an increase or decrease in the amount of biogas produced.

The introduction of an additional cogeneration unit to the wastewater treatment system requires a detailed financial and economic analysis taking into account both capital expenditure, operating costs, as well as the balance of heat treatment plant demand in relation to the amount of fees incurred for burning biogas in a flare.

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Abstract

The paper presents and discusses the 6-year effects of the operation of a biogas-fired cogeneration system which operates at the Rybnik Orzepowice sewage treatment plant. The qualitative composition of biogas, average daily amount of biogas produced, total demand of the sewage treatment plant for electricity and the amount of electricity obtained from biogas were presented. Regarding the average daily biogas production for the years 2013–2018, it can be stated that it remains at the level of 2,809 m^3/d (±33%). The average daily total electricity consumption for 2013-2018 remains at 8,846 kWh/d (-13.8%; +20.6%). The average daily amount of electricity produced from biogas for the years 2013-2018 remains at the level of 3,892 kWh/d (-38.7%; +10.1%). Electricity generated from biogas allows us to cover the demand of the treatment plant at 44% (minimum 39%, maximum 50%). In the analysed period, biogas consumption by individual facilities was: cogeneration unit approx. 65%, boilers: 10%, flare: 25%. Based on the operational data, it was calculated that: the unit indicator for biogas extraction from sewage, on average is 0.1584 m_n^3/m^3 (min. 0.0937 m_n^3/m^3, max .: 0.2291 m_n^3/m^3), the unit indicator for biogas extraction in relation to for COD load an average of 0.22 m^3 of biogas/kg COD (min. 0.09 m3 of biogas/kg COD, max. 0.47 m^3 of biogas/kg COD), the unit ratio of biogas extraction in relation to the BZT_5 load was on average 0.61 m^3 biogas/kg BZT_5 (min. 0.28 m^3 biogas/kg BZT_5, max. 1.20 m^3biogas/kg BZT_5).

Keywords:
biogas, cogeneration, heat, electricity, COD load, BZT_5 load

Ocena możliwości wprowadzenia układu kogeneracji w procesie zagospodarowania biogazu na przykładzie oczyszczalni ścieków w Rybniku Orzepowicach

Streszczenie

W artykule przedstawiono i omówiono 6-cio letnie efekty pracy układu kogeneracyjnego zasilanego biogazem, który pracuje w Oczyszczalni Ścieków Rybnik Orzepowice. Zaprezentowano skład jakościowy biogazu, średniodobową ilość wytwarzanego biogazu, całkowite zapotrzebowanie oczyszczalni na energię elektryczną oraz ilość energii elektrycznej uzyskiwanej z biogazu. Średniodobowa produkcji biogazu, za lata 2013-2018 można stwierdzić, że utrzymuje się ona na poziomie 2,809 m^3/d (±33%). Średniodobowe całkowite zużycie energii elektrycznej za lata 2013–2018, utrzymuje się on poziomie 8,846 kWh/d (-13,8%; +20,6%). Średniodobowa ilość produkowanej energii energii elektrycznej z biogazu za lata 2013–2018 utrzymuje się on poziomie 3,892 kWh/d (-38,7%; +10,1%). Energia elektryczna wytwarzana z biogazu pozwala na pokrycie zapotrzebowania oczyszczalni na poziomie 44% (minimalnie 39%, maksymalnie 50%). W analizowanym okresie zużycie biogazu przez poszczególne obiekty wynosiło: jednostka kogeneracyjna ok. 65%, kotły: 10%, pochodnia: 25%. Na podstawie danych eksploatacyjnych obliczono, że: jednostkowy wskaźnik pozyskania biogazu ze ścieków, średnio wynosi 0,1584 m_n^3/m^3 (min. 0,0937 m_n^3/m^3, max.: 0,2291 m_n^3/m^3), jednostkowy wskaźnik pozyskania biogazu w odniesieniu do ładunku ChZT średnio wynosił 0,22 m^3 biogazu/kg ChZT (min. 0,09 m^3 biogazu/kg ChZT, max. 0,47 m^3 biogazu/kg ChZT), jednostkowy wskaźnik pozyskania biogazu w odniesieniu do ładunku BZT5 średnio wynosił 0,61 m^3 biogazu/kg BZT_5 (min. 0,28 m^3 biogazu/kg BZT_5 w, max. 1,20 m^3 biogazu/kg BZT_5).

Słowa kluczowe:
biogaz, kogeneracja, ciepło, energia elektryczna, ładunek ChZT, Ładunek BZT_5