MIDDLE POMERANIAN SCIENTIFIC SOCIETY OF THE ENVIRONMENT PROTECTION
ŚRODKOWO-POMORSKIE TOWARZYSTWO NAUKOWE OCHRONY ŚRODOWISKA

Annual Set The Environment Protection
Rocznik Ochrona Środowiska

Volume/Tom 16. Year/Rok 2014 ISSN 1506-218X 16–33

Chemical Energy Balance of Digested Sludge in Sewage Treatment Plant Pomorzany in Szczecin

Władysław Szaflik[*], *Anna Iżewska*[*], *Mirosława Dominowska*[**]
[*]*Zachodniopomorski Uniwersytet Technologiczny, Szczecin*
[**]*Zakład Wodociągów i Kanalizacji, Szczecin*

1. Introduction

It is acknowledged, that the volume of treated municipal wastewater in its total volume is on the increase every year. Also, the volume of sludge generated in the treatment process will increase.

National Waste Management Plan assumes, that in 2022 there will be around 746 hundred Mg d.m. of sludge produced in Poland, i.e. 3 730 hundred Mg with hydration of about 80% [8].

Sludge includes in its composition over 50% of organic substance [3, 11–13, 19, 20, 22] and can be the source of renewable energy. The easiest way to gain energy from sludge is by exothermic methane digestion and emission of biogas – methane. Electric energy can be received from the energy that biogas contains. In methane fermentation process that takes place in Separate Sludge Digesters (SSD) heat is produced and biogas is emitted, and its main components are as following: methane CH_4, carbon dioxide CO_2, ammonia NH_3 and hydrogen sulphide H_2S [16]. Thanks to this process the volume of stored sludge decreases and limits its harmful effects on natural environment.

According to EU Directive 2001/77/WE of 27 September 2001 [10] amounts of energy from renewable energy sources (RES) were imposed on Member States. Therefore, acquisition and use of biogas produced during anaerobic stabilization of sludge for energy purposes becomes crucial.

The aim of this study is to determine the amount of energy released by sludge (initial and excessive) during fermentation process in the form of heat and produced biogas. These amounts were based on the balance of chemical energy of sludge supplied to and from SSD. The difference between the values was the energy that was emitted during biochemical processes in SSD in the form of heat and methane produced in the chamber.

Due to variability in the composition of supplied sludge, energy balance was done for an averaged measured calorific value of sludge supplied to and from SSD chambers from nine selected days (24 h) during four months in 2012.

2. Materials and methods

2.1. Description of Sewage treatment technology in Treatment Plant [4]

Sewage Treatment Plant Pomorzany treats wastewater from the left bank of Szczecin. As far as the Treatment Plant's catchment basin is concerned, a combined sewage system dominates in the older part of town, whilst a separate sewage system in the outskirts. Household sewage dominates in the catchment basin, whilst industrial waste is minimal. Due to the catchment basin's combined sewage system, during rains and snowmelts the volume of wastewater flowing into Treatment Plant during a day (24 h) is more than three times higher than during dry weather. Design parameters in Treatment Plant shown in Table 1 [15].

All wastewater flowing into the Treatment Plant goes to a plenum chamber, flows through a channel, on which a flow meter and automatic sampling apparatus are placed. Initially, the sample is treated mechanically.

In the first stage, sewage undergoes a filtration processes on grilles, where solid effluents are screened. The excess wastewater is discharged into two retention tanks with total capacity of 7000 m^3.

Table 1. Raw sewage design parameters of Treatment Plant Pomorzany [15]
Tabela 1. Parametry projektowe ścieków surowych Oczyszczalni Ścieków Pomorzany [15]

Population equivalent	419 000	-
Average daily flow	66 000	m^3/d
Average hourly flow	2 750	m^3/h
Maximum daily flow	79 200	m^3/d
The maximum hourly flow	3 990	m^3/h
Hourly minimum flow	900	m^3/h
Chemical oxygen demand	700	mg/dm
Biochemical oxygen demand	390	mg/dm
Suspended solids	270	mg/dm
Total nitrogen	65	mg/dm
Total phosphorus	10	mg/dm

After the biggest solid effluents are screened on grilles, sewage is directed to four aerated sand traps with a side grease chamber. The heaviest grit settles in sand traps as a result of sediment process. In addition, medium bubble aeration makes the waste spin, which enables to keep lighter organic suspension in sludge mass and the grit to fall, which creates conditions for flotation in the side chamber of the suspension lighter than sludge mass.

Grease collected from the surface of the side chamber with a scraper mounted on the sand trap's trolley bridge is scraped into the grease chamber where it is pumped into collection chamber and then pumped further to digesters.

From the Sand traps, sludge flows to four rectangular initial settling tanks with chain scrapers. In the settling tanks a sedimentation of flammable suspension takes place. The suspension settles to the bottom of the tanks, where it is periodically collected by chain scrapers into funnels. Then, in an automatic mode it is discharged to objects of sedimentation area as a unthickened primary sludge.

Grease that floats on the surface of the settling tank is taken away by a drainpipe, and then pumped into a collective chamber, and then, together with grease from sand traps, directed to digesters. Mechanically treated sludge is directed to Partition Chambers, where it is divided into three independent biological treatment lines.

Each Line includes:

- one predenitrification chamber of sludge, to which a slight part of raw sewage is supplied,
- one defosfatation chamber – designed as a circulating chamber
- two nitrification/denitrification chambers, designed as circulating Chambers of Carrousel type with fine bubble aeration. In the Chambers a process of simultaneous or alternate denitrification can be carried out,
- two secondary settlement tanks,
- pumping station of recirculated sludge with two propeller pumps,
- sludge waste pump.

In objects of biological degree pollutants are removed from wastewater as a result of metabolic processes occurring in living organisms of activated sludge. To support biological removal of phosphorus, a simultaneous physical-chemical precipitation is used with the help of trivalent iron salt. For this purpose, a PIX dosage installation was made, depending on technological conditions, to the spout of biological units (final precipitation), to the spout of sand traps (initial precipitation) and dispensing to digested sludge tanks in order to carry out sludge conditioning prior to the pass over to press.

The Sewage Treatment Plant additionally was equipped with an installation enabling PAX aluminum coagulant in case that filamentous bacteria occurs. The installation, similarly to PIX installation, consists of two tanks and a set of dosing pumps.

Biological blocks that have an entire metering measure a/o in each line in a continuous way the following: oxygen concentration, temperature, ammonia nitrogen concentration, nitrogen concentration, orthophosphate concentration, sludge concentration, measure of sludge layer's level in secondary settlement tanks.

Approved sludge treatment technology allows an entry of treated sludge that meet the sharpest demands of Polish Law to Odra River, which means for a sewage treatment plant over 100.000 RLM [15] Compilation of demanded parameters for sewage treatment and the actual obtained by Sewage Treatment Plant Pomorzany are presented in Table 2.

Table 2. Parameters of treated sewage discharged from Sewage Treatment Plant Pomorzany [4, 15]
Tabela 2. Parametry ścieków oczyszczonych odprowadzanych z Oczyszczalni ścieków Pomorzany [4, 15]

Parameters	Needs of water permit	Regulation of the Minister of the Environment of 2006, as amended [18]	The average of the measured values of the treated wastewater
BOD_5 [mg/dm^3]	15	15	5
COD [mg/ldm^3]	125	125	37
Suspended solids [mg/dm^3]	35	35	9
Total nitrogen*) [mg/dm^3]	10	10	9
Total phosphorus [mg/dm^3]	1	1	0.47

**For sewage temperatures above 12°C*

2.2. Sludge Management [4]

As far as Sewage Treatment Plant Pomorzany is concerned, obtaining demanded parameters of treated sewage is no problem. However, the more effective the sewage treatment, the more pollution remains after the treatment process.

Waste removed in the beginning of the mechanical treatment process, i.e. screenings – the leftovers after screening on grilles and sand – grit removed in sand traps, are exposed to rinsing only in order to minimize content of organic parts, and then to minimize water content by compression, in case of grilles, or separation on a screw conveyor, in case of sand. Waste prepared in this way – screenings and sand – is transported to appointed storage place. The amount of screenings and sand generated – ca. 30 tons per month.

The amount of collected initial and secondary sludge ca. 2.000 m^3/d and 99% content of water causes that sludge management in sewage treatment plant is a very important domain in exploitation matter as well as in techniques used. The main task of sludge treatment is minimizing the amount and volume by discharging a part of water and sludge treatment – so that there is no jeopardy to the natural environment. The first stage of proceedings with sludge depends on discharge of a part of water in thickening process. Due to different features of initial and surplus activated sludge, thickening is carried out differently.

Primary sludge is collected periodically from sludge funnel of primary settlement tanks and then thickened by gravity. This sludge is pumped into two gravity thickeners equipped with two rod agitators. In the thickeners, suspension falls to the bottom due to the influence of gravity and thickens, sludge supernatant is taken over from the surface of thickeners through overflow channels and drained to the Headworks. Thickened sludge from the bottom is periodically collected and transported to mixed thickened sludge tanks. Thickened surplus activated sludge is also supplied to this tank.

Surplus activated sludge is periodically collected from aeration tanks. As a result of biological structure of sludge, most of water included is water imbibed in cells. It is also harder to drain water, so called free water, water non–imbibed in cells, from sludge. This sludge is mechanically thickened in devices called thickening tables. Before sludge is supplied to the thickening device, a conditioning by polyelectrolyte takes place, which causes coagulation of sludge flocks and facilitates drainage of free water. Surplus activated sludge is thickened in 4 devices, each if which cooperates with two polyelectrolyte preparation station.

Primary sludge is thickened by gravity to ca. 5% d.m., surplus activated sludge is thickened in mechanical thickeners to ca. 6% d.m. Primary sludge and surplus activated sludge after being thickened is drained into thickened sludge tank where it is pumped into two closed digesters. Each digester has the capacity of 5.069 m^3, which assures ca. 20–day sludge residence time. Mesophile fermentation is conducted in digesters in temperature ca. 37°C. Sludge is mixed with the use of double impeller agitators suspended under a dome. Continuous circulation of sludge through spiral heat exchangers ensures steady support of defined temperature. The chambers work as overflow ones, sludge that is collected continuously from digesters, goes to digested sludge retention tank.

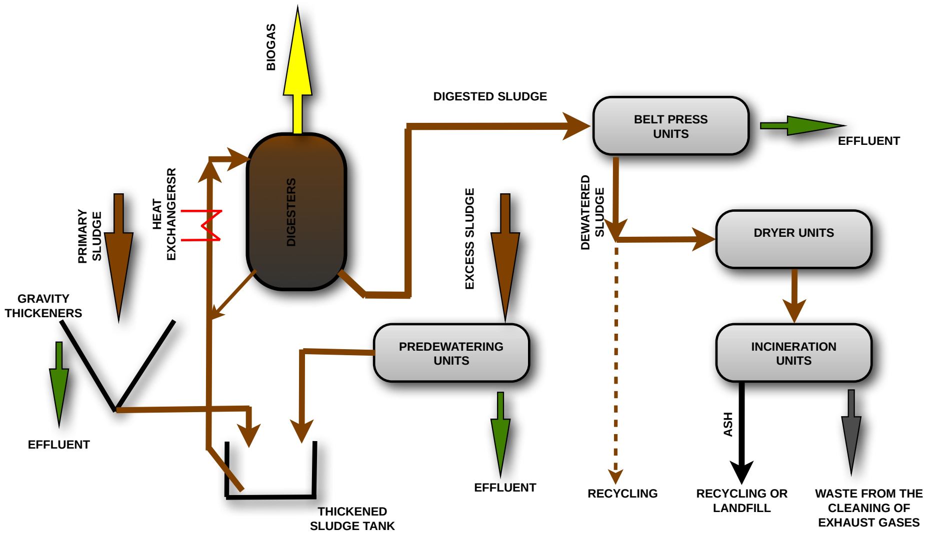

Fig. 1. Sludge management diagram [9]
Rys. 1. Schemat gospodarki osadowej [9]

Biogas produced in the chamber is accumulated in two–layer tanks with capacity of 1500 m^3 each and after desulphurization with bio-sulfex method (as a result of catalysis elemental sulphur is obtained) used as fuel in cogeneration aggregate (Fig. 1).

2.3. Chemical energy balance [4]

Chemical energy of sludge that goes through digesters in Sewage Treatment Plant Pomorzany was specified based on amount of sludge, content of dry matter in sludge and their heat of combustion before and after digestion and the amount of received biogas and heat of combustion calculated based on its chemical composition. Because the Chambers work as overflow ones, it was approved that the amount of supplied sludge to the chamber corresponds with the amount that is drained. In order to prepare the balance, a sludge energy balance of SSD scheme was assumed and shown in Fig. 2.

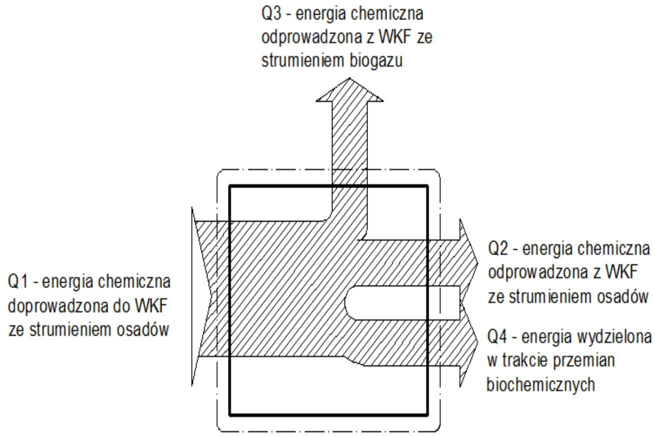

Fig. 2. Energy balance for sludge flowing through SSD and produced biogas [9]
Rys. 2. Bilans energii dla osadów przepływających przez WKF i wytwarzanego biogazu [9]

Energy balance can be show as follows:

$$Q_1 = Q_2 + Q_3 + Q_4 = Q_2 + Q_w \tag{1}$$

where:
Q_1 – chemical energy supplied to SSD with sludge stream [MJ],
Q_2 – chemical energy drained from SSD with sludge stream [MJ],
Q_3 – chemical energy drained from SSD with biogas stream [MJ],
Q_4 – energy emitted during biochemical changes of sludge [MJ],
Q_w – sum of energy emitted during biochemical changes of sludge and chemical energy drained from SSD with the biogas stream [MJ].

2.4. Energy supplied to SSD with sludge stream.

Amount of energy supplied to SSD with sludge stream was calculated based on dry matter charge supplied to digesters and marked heat of combustion.

$$Q_d = V_{os} \times z_{dsm} \times W_{udsm} \ \ [MJ] \tag{2}$$

where :
Q_d – energy supplied to SSD with sludge stream [MJ],
V_{os} – volume of supplied sludge to SSD Turing a Day (24h) [m^3],
z_{dsm} – content of dry matter in sludge supplied to SSD [kg/m^3],
W_{udsm} – heat of combustion of sludge supplied to SSD [MJ/kg].

2.5. Energy drained from SSD with sludge stream.

Amount of chemical energy drained from SSD with sludge stream was calculated similarly to the one supplied to SSD:

$$Q_2 = V_{os} \times z_{smo} \times W_{smo} \ \ [MJ] \qquad (3)$$

where:
Q_2 – energy supplied to SSD with sludge stream [MJ],
V_{os} – volume of sludge drained from SSD during a Day (24h) [m^3],
z_{smo} – content of dry matter in sludge supplied to SSD [kg/m^3],
W_{usmo} – heat of combustion of sludge supplied to SSD [MJ/kg].

2.6. Energy emitted during biochemical changes of sludge

Amount of energy emitted during biochemical changes of sludge was defined in transformed formula (4):

$$Q_w = Q_1 - Q_2 \qquad (4)$$

3. Measurement and calculation methodology

Separate Sludge Digesters (SSD) in Sewage Treatment Plant Pomorzany in Szczecin work as overflow ones, it is assumed that the volume of sludge supplied corresponds with the volume of drained sludge. In accordance to this, in order to establish the participation of energy emitted while biochemical changes that take place in SSD, one should refer to heat of combustion of dry matter included in one cubic meter of supplied and drained sludge. The content and volume of sludge supplied to the Sewage Treatment Plant is variable because sewage system supplies not only household sewage but also rain waters. In this situation the chamber plays a role of equalizing tank – sludge is drained from it of averaged compositions from the period of its detaining. Due to this role of the Chamber, in order to obtain competent results, heat of combustion of sludge was averaged for the period of time under analysis. Nine days (24 h) out of four months were chosen at random and the obtained results were averaged. In order to check if the balance was carried out in proper way, there was specified an average content of mineral parts in sludge supplied and drained, equal contents will show that the applied method was accurate to establish participation of energy emitted during biochemical changes that take place in SSD.

Samples of indigested sludge (at entry) to digesters were collected behind mixed sludge tank, to which primary sludge and surplus activated sludge is supplied after being thickened. The place for sampling was a stube pipe at main pipeline before a pump that pumps sludge into installation. Samples of indigested sludge (from exit of SSD) was collected behind indigested sludge tank, into which sludge from two digesters flows.

The place for sampling was a stube pipe on pipeline before press installation. Sludge is stirred both in thickened sludge tank (before digestion) and digested sludge tank. It is stirred with high-speed submersible agitator, which influences on good mixing and homogenization of material destined to analysis. In order to increase representativeness of the sample, within a day (24 h) equal amount of sludge was sampled – 500 ml four times during a day (24 h) at regular intervals at 1.00, 7.00, 13.00 and 19.00. All samples taken in each sample point during a day (24h) were stirred and further samples were taken for lab tests numbers. Places of sludge sampling were presented in Fig. 3.

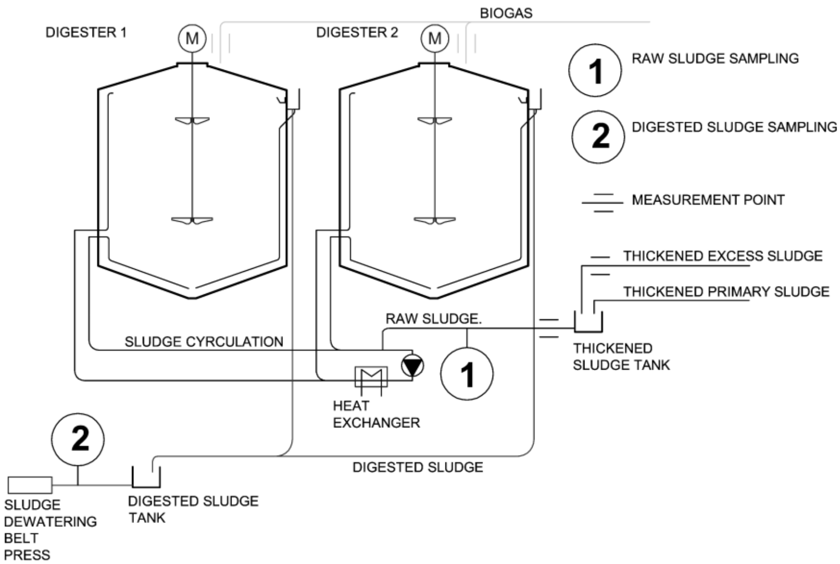

Fig. 3. Sludge digestion installation scheme with marking of samples and sample points for streams of sludge and biogas [9]

Rys. 3. Schemat instalacji fermentacji osadów z oznaczeniem miejsc poboru próbek i miejsc pomiarów strumieni osadów i biogazu [9]

The next element of the examinations were laboratory analyses of sludge supplied to and drained from digestion chambers. The content of dry matter was marked appropriately to EN-12990:2002 norm of Sludge Characteristics. Marking of dry residues and water content. The content of organic parts in dry matter was marked according to EN 12979:2002 norm of Sludge Characteristics – marking of dry matter ignition loss of sludge mass. Heat of combustion together with laying out calorific value (as in PN-EN-ISO 9931:2005) was carried out in IKA 2004 calorimeter of calorific value designation uncertainty of 44 kJ/kg d.m.

4. Results of measeurements and calculations

In table no 3 compiled were the following: content of dry matter, content of mineral parts and heat of combustion for supplied raw sludge and digested sludge drained from SSD.

An average content of mineral parts in sludge supplied amounted to 13.17 kg/m^3 and in drained one 11.99 kg/m^3, while standard divergence 2.06 and 0.61 respectively.

The difference in the average amount of minerals brought and discharged into the digester Secreted during the day as the extension of time will decrease. For a very long time will be zero - the amount of mineral matter brought will be responsible drained. If you will be a test of the amount of inorganic sediment, draw the appli-seconds, it will provide them with the correct execution. Hypothesized null H_0 of the equality of the content of mineral substances in sewage influent and discharged to the SSD. It was assumed that the distribution of the volatility of mineral substances in the sediment is described normal distribution. Due to averaging the composition of the sludge in SSD test was performed for medium unconnected. Table 4 represented lays calculation results.

Table 3. Compilation of the dry matter content, mineral parts and sludge heat of combustion supplied to and drained from digesters [9]
Tabela 3. Zestawienie zawartości suchej masy, części mineralnych oraz ciepła spalania osadu doprowadzanego i odprowadzanego z komór fermentacyjnych [9]

Date	Raw sludge			Digested sludge		
	dry matter content	content of mineral	Heat of combustion	Dry matter content *	content of mineral	heat of combustion
	kg/m^3	kg/m^3	MJ/kg dm	kg/m^3	kg/m^3	MJ/kg dm
04.04.2012	59.7	14.4	17.02	31.0	12.1	13.51
17.04.2012	44.7	10.6	15.94	30.9	12.5	12.92
09.05.2012	43.7	10.5	16.13	32.4	12.0	13.99
22.05.2012	51.9	12.9	16.39	31.3	11.1	12.67
05.06.2012	50.1	12.7	16.04	31.6	11.3	13.40
03.07.2012	49.9	14.0	16.26	31.0	11.5	13.44
17.07.2012	50.1	15.1	14.95	31.9	11.9	11.93
25.07.2012	43.0	11.9	15.25	33.3	12.9	12.59
31.07.2012	49.7	16.4	14.44	32.5	12.7	12.99
Average	49.0	12.70	15.92	31.7	11.99	13.04
Standard divergence	5.11	2.06	0.81	0.83	0.62	0.61

**where, DM – dry matter content in the sludge*

Table 4. Equality check of amounts of inorganic substances in sediments before and after the SSD
Tabela 4. Sprawdzenie równości ilości substancji nieorganicznych w osadach przed i po WKF

Parameter	Model	The value calculated
The variance of the sample	$s^2 = \frac{(n_A - 1)s_A^2 + (n_B - 1)s_B^2}{n_A + n_B - 2}$	2.32
Deviation of the aver-age for the sample	$s_d = \sqrt{s^2\left(\frac{1}{n_A} + \frac{1}{n_B}\right)}$	0.71
Empirical parameter distribution t Studenta	$t_{emp} = \frac{\bar{x}_A - \bar{x}_B}{s_d}$	0.72
Parameter theoretical distribution t studenta	$t_{\alpha=0.05,\ \nu=9+9-2}$	2.12

Because $t_{emp} = 0.72 < t_{0,05} = 2.12$, then the probability of error of less than 0.05 was found that the average mineral content in the sediment adjusted and-discharged SSD is the same.

Deviation from standard of mineral substances' content should be noted; it is much higher for supplied sludge (2.06), rather than drained sludge (0.62) from SSD. This gives evidence that Separate Sludge Digesters work as a tank, which averages compositions of sludge. Calculated maximum error for determination of heat of combustion supplied to SSD does not exceed 1.5%, while sludge supplied does not exceed 2.0%.

Table 5. presents energy balance of sludge flowing through Separate Sludge Digesters. Maximum error for designation of sludge chemical energy value used in SSD in particular days changes within the scope from 4 to 9%.

Table 5. Energy balance of sludge energy flowing through SSD
Tabela 5. Bilans energii osadów przepływających przez WKF

Date	The heat of combustion of sludge		Part of the energy used in chemical precipitate SSD
	Brought to the SSD	Discharged from the SSD	
	MJ/(m^3 sludge)	MJ/(m^3 sludge)	MJ/(m^3 sludge)
04.04.2012	999.07	419.91	590.26
17.04.2012	712.52	397.94	314.59
09.05.2012	704.99	453.29	251.61
22.05.2012	949.00	396.57	452.43
05.06.2012	903.60	423.44	390.16
03.07.2012	911.37	416.64	394.73
17.07.2012	749.00	376.19	372.90
25.07.2012	655.75	419.91	236.94
31.07.2012	703.23	422.19	291.05
Average	776.49	413.77	362.72
Aberrance	133.96	21.70	x
Percent [%]	100.0	53.3	46.7
Aberrance [%]	17.5	5.2	x

Percentage value of average chemical energy amount was established, which was changed into heat and emitted with methane. Average value amounts to 362.7 MJ/(m^3 sludge) equivalent 46.7% chemical energy supplied to the sludge SSD. Confidence interval for the average was established, and it was accepted, 0,95 level of confidence interval was approved. Percentage average value of the energy amount changed into heat and emitted with methane in relation to chemical energy of sludge supplied to SSD for Sewage Treatment Plant Pomorzany in Szczecin ranges 362.7 ± 79.2 MJ/(m^3 sludge). This is equivalent to quantity of energy supplied to the WKF 46.7% ± 9.8% (Table 6).

Table 6. Equality check of amounts of inorganic substances in sediments before and after the SSD
Tabela 6. Sprawdzenie równości ilości substancji nieorganicznych w osadach przed i po WKF

Parameter	Model	The value calculated
The variance of the difference	$s^2 = \frac{(n_A - 1)s_A^2 + (n_B - 1)s_B^2}{n_A + n_B - 2}$	9207
Mean deviation for the difference	$s_d = \sqrt{s^2\left(\frac{1}{n_A} + \frac{1}{n_B}\right)}$	45.2
Parameter theoretical distribution t studen-ta	$t_{\alpha=0.05,\ \nu=9+9-2}$	1.75
Standard divergence	$s_d\ t_{\alpha=0.05,\ \nu=9+9-2}$	79.2

5. Conclusions

The article presents energy analysis results of Separate Sludge Digesters work in Sewage Treatment Plant Pomorzany. The result received ranges in the scope of values published in literature [2]. Analyzing dry matter content of sludge examined, which amounts from 43.0 to 59.7 kg/m^3 for raw sewage, it was established that it is close to values provided by [19–21].

Average content of mineral parts in sludge supplied and drained ranges in the boundaries provided by literature [12–14, 17]. However, Shen and Zhang as well as Stelmach and Wasielewski [19, 21] come to conclusion that the content of ash in sludge is higher and amounts to 22.6 and 36.8% respectively. Calorific value (heat of combustion) of sludge supplied to SSD is similar to the one presented by Bien, Dabrowski and Piecuch, Stelmach and Wasilewski as well as Werl and Wilk [1, 5–8, 21, 23]. Low heat of combustion and low calorific value of examined sludge after digestion, that amounted from 11.93 to 13.99 MJ/kg dm can result from kind of drainage and content of nitrogen, coal, ratio of coal to nitrogen, hydrogen to sulphur. Heat of combustion (calorific value) of sludge after digestion corresponds with medium–digested sludge. Percentage value of average amount of chemical energy changed into heat and emitted with methane in relation to chemical energy of sludge supplied to SSD for Sewage Treatment Plant Pomorzany in Szczecin ranges in 46.7 ± 11.3%.

Authors in their further works intend to estimate shares of chemical energy changed into heat and emitted with methane in Separate Sludge Digesters in Sewage Treatment Plant Pomorzany in Szczecin.

Authors of the article thank the Management of Water and Sewage Company in Szczecin for the access to data and results of sludge laboratory analyses in Sewage Treatment Plant Pomorzany.

References

1. **Bień J.:** *Osady ściekowe. Teoria i praktyka.* Wyd. Politechniki Częstochowskiej, Częstochowa 2007.
2. **Cornel P., Meda A., Bieker S.:** *Wastewater as a source of energy, nutrients and service water*. Treatise in Water Science. Elsevier Verlag (2011).
3. **Czekała J.:** *Osady ściekowe źródłem materii organicznej i składników pokarmowych.* Fol. Univ. Agric. Stetin. 200 Agricultura (77), 33–39 (1999).
4. Dane eksploatacyjne Oczyszczalni Ścieków Pomorzany otrzymane z Zakładu Wodociągów i Kanalizacji Sp. z o.o. w Szczecinie. Szczecin 2012.
5. **Dąbrowski J., Piecuch T.:** *Badania laboratoryjne nad możliwością osadów ściekowych wraz z odpadami gumowymi.* Inżynieria Ekologiczna 25, (2011).
6. **Dąbrowski J., Piecuch T. B.:** *Badania laboratoryjne nad możliwością współwspalania miału węglowego wraz z osadami ściekowymi.* Przegląd Górniczy. 11, (2010).
7. **Dąbrowski J., Piecuch T.:** *Badania laboratoryjne nad możliwością współwspalania wybranych grup odpadów tworzyw sztucznych wraz z osadami ściekowymi.* Polityka Energetyczna 14 (1), (2011).
8. **Dąbrowski J., Piecuch T.:** *Mathematical Description of Combustion process of Selected Groups of Waste.* Rocznik Ochrona Środowiska (Annual Set The Environment Protection) 11, 253–268 (2011).
9. **Dominowska M.:** *Bilans energetyczny Wydzielonej Komory Fermentacyjnej Oczyszczalni Ścieków Pomorzany w Szczecinie*. Praca dyplomowa magisterska prowadzona przez prof. dr hab. inż. Władysława Szaflika. Szczecin 2012.
10. Dyrektywa 2001/77/WE Parlamentu Europejskiego i Rady z dnia 27 września 2001 r. w sprawie wspierania produkcji na rynku wewnętrznym energii elektrycznej wytwarzanej ze źródeł odnawialnych (Dz. Urz. L 293/33 z dnia 27.09.2001).

11. **Laturnus F., von Arnold K., Gron C.:** *Organic Contaminants from Sewage Sludge Applied to Agricultural Soils.* Env Sci Pollut. Res. 14, Special Issue 1, 53–60 (2007).
12. **Maćkowiak Cz.:** *Skład chemiczny osadów ściekowych ich wartość nawozowa, "*Charakterystyka i zagospodarowanie osadów ściekowych" Bydgoskie Towarzystwo Naukowe. Prace Wydziału Nauk Technicznych seria A 2000, 30, 16–21 (2000).
13. **Ndaji F.E., Ellyatt W.A.T., Malik A.A., Thomas K.M.:** *Temperature programmed combustion studies of coal and waste materials*. Fuel 78, 301–307 (1999).
14. **Pierścieniak M., Bartkiewicz B.:** *Zagospodarowanie biogazu powstającego w procesie fermentacji metanowej w oczyszczalniach ścieków.* Ochrona Środowiska i Zasobów Naturalnych, nr 47, 47–61 (2011).
15. Praca zbiorowa: Dokumentacja powykonawcza Oczyszczalni Ścieków Pomorzany.
16. **Roati C., Fiore S., Ruffino B., Marchese F., Novarino D., Zanetti M C.:** *Preliminary evaluation of the potential biogas production of food-processing industrial wastes.* American J. of Environmental Sciences 8(3), 291–296 (2012).
17. **Roca-Perez L., Martinez C., Marcilla P., Boluda R.:** *Composting rice straw with sewage sludge and compost effects on the soil-plant system.* Chemosphere (2009), doi: 10.1016/j.chemosphere.2009.12.059
18. Rozporządzenie Ministra Środowiska z 2006 r w sprawie warunków jakie należy spełnić przy wprowadzaniu ścieków do wód lub do ziemi, oraz w sprawie substancji szczególnie szkodliwych dla środowiska wodnego (Dz. U. z dnia 24 lipca 2006 r. nr 137 poz. 994 z póź. zm.)
19. **Shen L., Zhang D.:** *An experimental study of oil recovery from sewage sludge by low–temperature pyrolysis in a fluidized-bed.* Fuel 82, 465–472 (2003).
20. **Stańczyk-Mazanek E., Piatek M., Kępa U.:** *Wpływ następczy osadów ściekowych stosowanych na glebach piaszczystych na właściwości kompleksu sorpcyjnego.* Rocznik Ochrona Środowiska 15 (3), 2437–2451 (2013).
21. **Stelmach S., Wasielewski R.:** *Co-combustion of dried sewage and coal in a pulverized coal boiler*. J. Mater Cycles Waste Manag. 10, 110–115 (2008).
22. **Torii S.I., Lavado R.:** *Zinc distribution in soils amended with different kinds of sewage sludge.* J. Environmental Management 99, 1571–1579 (2009).
23. **Werle S., Wilk R.K.:** *A review of methods for the thermal utilization of sewage sludge: The Polish perspective.* Renewable Energy 35, 1914–1919 (2010).

Bilans energii chemicznej przefermentowanych osadów Oczyszczalni Ścieków Pomorzany w Szczecinie

Streszczenie

W pracy omówiono technologię oczyszczania ścieków w Oczyszczalni Ścieków Pomorzany w Szczecinie. Następnie scharakteryzowano gospodarkę osadami ściekowymi w tej oczyszczalni. Po tym wprowadzeniu przedstawiono bilans energii chemicznej doprowadzanych do Wydzielonych Komór Fermentacyjnych i odprowadzanych z niej osadów ściekowych. Przedstawiono także sposób określania elementów bilansu energii i przeprowadzono analizę niepewności wyników i bilansu energii. Określono ilość energii produkowanej z osadów podgrzewanych do temperatury 37°C w czasie fermentacji i energii przechodzącej do biogazu oraz ich udział procentowy w energii chemicznej dostarczanej z osadami. W wyniku przeprowadzonych badań stwierdzono, że procentowa wartość średnia ilości energii chemicznej zamienionej na ciepło i odprowadzonej z wyprodukowanym z nich metanem względem energii chemicznej ścieków doprowadzonych do WKF dla Oczyszczalni Ścieków Pomorzany w Szczecinie mieści się w przedziale 46,7% ± 9,8%.

Słowa kluczowe: oczyszczalnia ścieków, osady przefermentowane, bilans energii chemicznej
Key words: wastewater treatment plant, digested sludge, chemical energy balance