ARCHIVES OF ENVIRONMENTAL PROTECTION

vol. 38 no. 1 pp. 103 - 114 2012

VERSITA

PL ISSN 2083-4772
DOI: 10.2478/v10265-012-0009-5

EFFECT OF THERMAL DISINTEGRATION OF EXCESS SLUDGE ON THE EFFECTIVENESS OF HYDROLYSIS PROCESS IN ANAEROBIC STABILIZATION

IWONA ZAWIEJA*, PAWEŁ WOLSKI

Institute of Environmental Protection
Czestochowa University of Technology
Brzeźnicka 60 A,,
42-200 Czestochowa, Poland
*Corresponding author's e-mail: izawieja@is.pcz.czest.pl

Keywords: Excess sludge, thermal disintegration, hydrolysis, anaerobic stabilization, degree of sludge fermentation, volatile fatty acids, chemical oxygen demand.

Abstract: The factor which essentially affects sludge biodegradation rate is the degree of fluidization of insoluble organic polymers to the solved form, which is a precondition for availability of nutrients for microorganisms. The phases which substantially limit the rate of anaerobic decomposition include hydrolytic and methanogenic phase.

Subjecting excess sludge to the process of initial disintegration substantially affects the effectiveness of the process of anaerobic stabilization. As a result of intensification of the process of hydrolysis, which manifests itself in the increase in the value and rate of generating volatile fatty acids (VFA), elongation of methanogenic phase of the process and increase in the degree of fermentation of modified sludge can be observed. Use of initial treatment of sewage sludge i.e. thermal disintegration is aimed at breaking microorganisms' cells and release of intracellular organic matter to the liquid phase. As a result of thermal hydrolysis in the sludge, the volatile fatty acids (VFA) are generated as early as at the stage of the process of conditioning. The obtained value of VFA determines the course of biological hydrolysis which is the first phase of anaerobic stabilization.

The aim of the present study was to determine the effect of thermal disintegration of excess sludge on the effectiveness of the process of hydrolysis in anaerobic stabilization i.e. the rate of production of volatile fatty acids, changes in the level of chemical oxygen demand (COD) and increase in the degree of reduction in organic matter. During the first stage of the investigations, the most favourable conditions of thermal disintegration of excess sludge were identified using the temperatures of 50°C, 70°C, 90°C and heating times of 1.5 h − 6 h. The sludge was placed in laboratory flasks secured with a glass plug with liquid-column gauge and subjected to thermal treatment in water bath with shaker option. Another stage involved 8-day process of anaerobic stabilization of raw and thermally disintegrated excess sludge. Stabilization was carried out in mesophilic temperature regime i.e. at 37°C, under periodical conditions. In the case of the process of anaerobic stabilization of thermally disintegrated excess sludge at the temperature of 50°C and heating time of 6 h (mixture B) and 70°C and heating time of 4.5% (mixture C), the degree of fermentation of 30.67% and 33.63%, respectively, was obtained. For the studied sludge, i.e. mixture B and mixture C, maximal level of volatile fatty acids i.e. 874.29 mg CH_3COOH/dm^3 and 1131.43 mg CH_3COOH/dm^3 was found on the 2nd day of the process. The maximal obtained value of VFA was correlated on this day with maximal COD level, which was 1344 mg O_2/dm^3 for mixture B and 1778 mg O_2/dm^3 for mixture C.

INTRODUCTION

The effect of initial treatment of sewage sludge on improved efficiency of methane fermentation is a promising research problem, both in terms of economics of the stabilization process and potential benefits resulting from fermentation technology i.e. increase in the degree of conversion of organic compounds to gaseous form (biogas). The degree of fluidization of insoluble organic polymers to a soluble form, available for microorganisms, has essential effect on the speed of sludge biodegradation. The phases which substantially limit the rate of anaerobic decomposition are hydrolytic and methanogenic phase.

In order to facilitate the process of anaerobic stabilization, excess sludge should be subjected to the process of initial disintegration, which is a precondition for an increase in the effectiveness of the process [1, 2, 3, 4].

Waste activated sludge (WAS) is the main by-product in the process of biological waste treatment [5]. As a result of intensification of the process of hydrolysis, the methanogenic phase is elongated, which, in consequence, causes substantial increase in biogas production. The obtained biogas is a valuable energy carrier with high calorific value which allows for meeting the energy demand in the wastewater treatment plant, generation of heat for central heating system and electricity used for direct power supply to the equipment.

The use of initial treatment of sewage sludge, e.g. thermal modification of the sludge, is aimed at breaking microorganisms' cells in the excess sludge, which is a precondition for release of intracellular organic matter to the liquid phase. As a result of thermal hydrolysis in the sludge, the volatile fatty acids (VFA) are generated as early as at the stage of the process of conditioning. The obtained value of VFA determines the course of biological hydrolysis, which is the first phase of anaerobic stabilization. Increase in the rate of generation of VFAs and increase in their values on consecutive days of acid fermentation directly affect the effectiveness of biogas production [6, 7, 8]. During the process of anaerobic stabilization, initiation of thermal hydrolysis allows for obtaining higher degree of transformation of volatile fatty acids (VFA) into methane. Shortening of the duration of hydrolytic phase causes intensification and acceleration of the processes which take place in individual stages of anaerobic stabilization. The methods of thermal disintegration of sewage sludge include in particular [7, 9]:

– low-temperature methods, at the temperatures below 100°C,

– high-temperature methods, at the temperatures over 100°C.

The literature [10] reports that thermal sludge treatment impacts significantly on the increase in biogas acquisition. Thermal hydrolysis (20 min at the temperature of 170°C) caused over 70% reduction in the content of dry matter at over 3-time increase in the load in the chamber with organic mass. The process of hydrolysis at lower temperatures (60÷80°C) favourably affects the composition of the obtained hydrolysate, but it requires longer times of reaction (60÷120 min) [11, 12]. In the result of disintegration followed stimulation of the inert part of excess sludge which significantly affect the intensification of the methane fermentation [13]. Moreover, the investigations carried out by Dąbrowska *et al.* [14] confirmed that after the process of thermophilic digestion of the mixture of primary and fermenting sludge, the total concentration of seven PCBs was reduced by 84%, which suggests that thermophilic digestion affects reduction in PCBs positively.

MATERIALS AND METHODS

Characterisation of the Study Substrate

The substrate in the study was excess sludge (90%), and fermented sludge (10%) which was used for inoculation. The sludge was sampled from the Warta Central Sewage Treatment Plant in Częstochowa. Excess activated sludge samples used for the investigations were taken immediately before mechanical densification. Excess sludge which is generated at the biological level is supplied to mechanical concentrators and, after densification to ca. 5−6% of dry matter, is pumped to WKF_z. The effluent waters which are generated in the process are discharged in front of primary settling tanks. Raw and excess sludges, accumulated in WKF_z, are subjected to methane fermentation at the temperature of 33°C.

The following mixtures of sludge were subjected to methane fermentation:

− Mixture A – raw excess sludge + fermented sludge

− Mixture B – excess sludge, thermally disintegrated at the temperature of 50°C for 6 h + fermented sludge;

− Mixture C – excess sludge, thermally disintegrated at the temperature of 70°C for 4.5 h + fermented sludge.

Studies of anaerobic stabilization process do not include mixture D, pre-tested at the stage of selecting the most favorable conditions for thermal disintegration. In the case of mixture D, despite the increase in pretreatment temperature by 20°C in reference to mixture C, a satisfactory increase in the value of COD was not obtained, due to the nature of the physico-chemical properties of organic substances contained in the sludge with increasing preparation time, while watching the decline in VFA. Table 1 presents the characteristics of raw excess sludge and fermented sludge used in the study.

Conditions of Thermal Disintegration of Excess Sludge

In order to determine the most favourable conditions of thermal modification of excess sludge, the temperatures of 50°C, 70°C and 90°C were selected for heating for the period of 1.5 h; 3 h; 4.5 h and 6 h. The sludge poured to laboratory flasks was secured from air access with a glass plug with liquid-column gauge and placed in water bath. The sample volume was 500 ml.

Conditions for the Process of 8-day Anaerobic Stabilization

The laboratory experiments were aimed at the determination of the impact of thermal disintegration of excess sludge on the efficiency of hydrolysis process in anaerobic stabilization, i.e. intensity of generation of volatile fatty acids (VFA). The process of methane fermentation was carried out in eight glass laboratory flasks, which performed the role of fermentation chambers. Before the process, laboratory flasks with the volume of 0.5 dm^3 were secured from air access with plugs with diameter of 33 mm and glass liquid-column gauges, which allowed for discharge of the generated biogas. They were placed in laboratory thermostat at the temperature of 37°C. The flasks were mixed manually, once a day, in order to mix the whole volume of the sludge and prevent from generation of the skin on the surface and creation of the areas overloaded with contaminants.

The following physical and chemical determinations were carried out:

– pH using pH meter by Cole Palmer 59002 – 00, according to (PN-9/C-04540/05) [15],

Table 1. Selected physical and chemical parameters of sludge for the mixtures A, B and C

	Dry mass	Dry min. mass	Dry org. mass	VFAs	COD	Alkalinity	Acidity	Ammonium nitrogen	Nitrogen	pH
	g/dm^3	g/dm^3	g/dm^3	$mgCH_3COOH/dm^3$	mgO_2/dm^3	$mgCaCO_3/dm^3$	$mgCaCO_3/dm^3$	$mgN\text{-}NH_4^+/dm^3$	mgN/dm^3	–
MIXTURE A, MIXTURE B	**FERMENTED SLUDGE (inoculum)**									
	18.03	6.38	11.65	823	1358	3300	200	28	43	7.60
	RAW EXCESS SLUDGE									
	8.98	1.99	6.99	103	165	220	140	28	30	7.65
MIXTURE C	**FERMENTED SLUDGE (inoculum)**									
	19.60	7.24	13.36	617	1021	2700	240	25	56	7.63
	RAW EXCESS SLUDGE									
	9.81	3.15	6.67	86	70	120	20	27	31	7.26

– dry matter, organic dry matter, mineral dry matter according to (PN-EN-12879) [16],
– volatile fatty acids (VFA) by means of distillation with water vapour according to (PN-75/C-04616/04) [17],
– alkalinity according to (PN-91/C-04540/05) [18],
– acidity according to (PN-91/C-04540/05) [19],
– chemical oxygen demand using dichromate method according to (ISO 7027) [20],
– total Kjeldahl nitrogen according to (PN-73/C-04576/10) [21],
– amone nitrogen according to (PN-73/C-04576/02) [21].

RESULTS AND DISCUSSION

Choice of the Most Favourable Parameters of Thermal Disintegration of Excess Sludge

In order to choose the most favourable temperature and conditioning time, excess sludge was subjected to three test cycles in the range of low temperatures, i.e. the temperature of 50°C, 70°C and 90°C and conditioning time of 1.5; 3; 4.5; 6h. The criterion for selection of parameters was the increase in concentration of organic substance in sludge liquor of excess sludge measured by means of COD and VFA indexes. The content of organic dry matter in the excess sludge before the process of thermal conditioning amounted to 9.68 g/dm^3. Table 2 presents changes in COD levels in sludge liquor after the process of thermal conditioning, whereas changes in VFA levels are presented in Fig. 1.

Table 2. Changes in COD levels in sludge liquor in excess sludge subjected to thermal conditioning recorded depending on time and temperature of preparation.

COD, mgO$_2$/dm^3				
Temp. °C \ Time, h	1.5	3	4.5	6
50	1315	1398	1489	1566
70	1816	2104	2398	2374
90	1970	2062	2158	2366

The obtained results confirm the theory of Wójtowicz [13] concerning a positive effect of disintegration on fluidization of organic matter contained in excess sludge, with its direct manifestation being an increase in COD and VFAs in sludge liquor. The lowest value of COD in sludge liquor was found for the temperature of 50°C, with heating time of 1.5 h (1315 mgO$_2$/dm^3), whereas its higher level of 2398 mgO$_2$/dm^3 was observed for the temperature of 70°C and heating time of 4.5 h.

It was found during the process that the most favourable value of volatile fatty acids during 6-hour conditioning was obtained for the temperature of 70°C i.e. 428.57 mg CH_3COOH/dm^3. In the case of 6-hour conditioning, the value of VFA for all the temperatures rose with respect to the initial value. Downward trend for VFA level after

1.5 h of heating was observed for the temperature of 90°C. For the heating time of 1.5 h the level of VFAs reached 197.14 mg CH_3COOH/dm^3, whereas for the time of 6 h, this value was 154.27 mg CH_3COOH/dm^3.

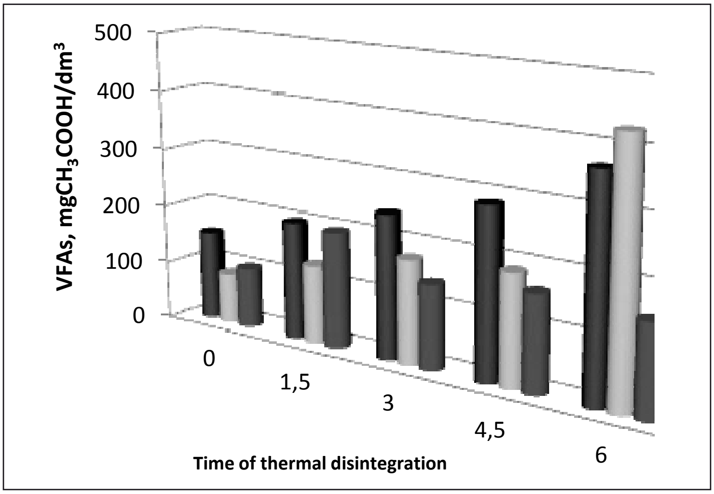

Fig. 1. Changes in the VFA level observed in sludge liquor as a function of exposure time and disintegration temperature

Process of Methane Fermentation in Raw Excess Sludge

The process of 8-day anaerobic stabilization was carried out for the mixture of non-conditioned excess sludge (90%) and fermented sludge (10%) (mixture A).

Degree of fermentation of the sludge for mixture A amounted to 16.88%. The content of organic dry matter before the process amounted to 5.39 g/dm^3, whereas this value was 4.48 g/dm^3 on the last day of the process. The reduction in the content of dry matter from 9.44 g/dm^3 before the process to 6.92 g/dm^3 after the process was observed. Reduction in dry matter of the sludge amounted to 26.70%. Value of volatile fatty acids before the process of anaerobic stabilization amounted to 111.43 mg CH_3COOH/dm^3; its maximal level was observed on the 3rd day of the process, i.e. 771.43 mg CH_3COOH/dm^3. A decline in the level of VFAs was initiated on the 4th day and, on the 8th day, VFA level amounted to 377.14 mg CH_3COOH/dm^3. Value of COD for sludge water before the process amounted to 288 mg O_2/dm^3, the highest value was reached on the third day and amounted to 1123 mg O_2/dm^3; a decline in the level of COD was observed from the fourth day, and, on the last day of the process this value amounted to 454 mg O_2/dm^3. Table 3 presents comparison of the results obtained for the course of the process of anaerobic stabilization in raw excess sludge (mixture A).

Process of Methane Fermentation of Thermally Disintegrated Excess Sludge

The process of 8-day anaerobic stabilization was employed for the mixture of excess sludge (90%) thermally conditioned at the temperature of 50°C for 6 h and fermented sludge (mixture B) and the mixture of the sludge thermally conditioned at the temperature of 70°C for 4.5 h and fermented sludge (10%) (mixture C).

Table 3. Selected physical and chemical parameters of the mixture A (raw excess sludge + fermented sludge) subjected to the process of 8-day anaerobic stabilization

Time of methane fermentation	Dry mass	Dry min. mass	Dry org. mass	VFAs	COD	Alkalinity	Acidity	Ammonium nitrogen	Nitrogen	pH
d	g/dm^3	g/dm^3	g/dm^3	$mgCH_3COOH/dm^3$	mgO_2/dm^3	$mgCaCO_3/dm^3$	mg/dm^3	$mgN\text{-}NH_4^+/dm^3$	mgN/dm^3	–
0	9.44	3.91	5.39	111.43	288	500	20	56.00	60.00	7.78
1	9.13	3.15	5.54	445.71	688	620	60	112.00	106.00	7.62
2	9.05	3.82	5.23	548.57	948	880	80	165.20	140.00	7.12
3	8.56	2.29	6.27	771.43	1123	1100	140	218.40	196.00	7.02
4	9.41	3.47	5.94	651.43	937	1100	136	221.20	198.80	7.11
5	9.48	4.24	5.24	514.29	824	1180	124	218.40	224.00	7.23
6	8.63	4.57	4.06	437.14	737	1250	100	215.60	246.40	7.32
7	7.75	3.16	4.59	394.29	606	1320	128	224.00	196.00	7.43
8	6.92	3.15	4.48	377.14	454	1240	180	280.00	252.00	7.18

The degree of fermentation of the sludge for mixtures B and C amounted to 30.67% and 33.63%, respectively. In the case of mixture B, the content of organic dry matter before the process was 6.37 g/dm^3, whereas on the last day of the process this value was 4.41 g/dm^3. The content of dry matter before the process of fermentation amounted to 9.30 g/dm^3, whereas after the process it reached 5.43 g/dm^3. Reduction in dry matter of the sludge amounted to 41.62%. For mixture C, the content of organic dry matter before the process amounted to 7.24 g/dm^3, whereas on the last day of the process this value was 5.37 g/dm^3. The content of dry matter before the process of fermentation amounted to 10.93 g/dm^3, whereas after the process it was 8.55 g/dm^3. Reduction in dry matter of the sludge was 21.78%. In the case of mixtures B and C, the level of volatile fatty acids before the process of anaerobic stabilization amounted to 188.57 mg CH_3COOH/dm^3 and 342.86 mg CH_3COOH/dm^3, respectively. Maximal values for both mixture B and mixture C was observed on the 2nd day of the process and they reached 874.29 mg CH_3COOH/dm^3 and 1131.43 mg CH_3COOH/dm^3, respectively. A decline in the VFA level was observed on the third day of the process and, on the 8th day, this value was 171.43 mg CH_3COOH/dm^3 in mixture B and 377.14 mg CH_3COOH/dm^3 in mixture C. In the case of mixture B, the value of COD in sludge water before the process was 640 mg O_2/dm^3; its highest level (1344 mg O_2/dm^3) was found on the 2nd day and a decline in COD level in the sludge liquor was observed from the third day and it continued until it was 280 mg O_2/dm^3 on the last day.

In mixture C, value of COD before the process of stabilization amounted to 1826 mg O_2/dm^3 and it was the highest level reached during the study. A decline in the value of COD in sludge liquor was observed from the first day and dropped to 800 mg O_2/dm^3 on the last day of the process.

Tables 4 and 5 present comparison of the results obtained for the process of anaerobic stabilization of thermally disintegrated excess sludge (mixtures B and C).

The results concerning the course of the process of anaerobic stabilization of thermally modified excess sludge confirm the effectiveness of this method as a disintegrating factor, which was also confirmed by the studied by other researchers [10, 11, 12].

CONCLUSIONS

The aim of the present study was to identify the effect of thermal method of disintegration of excess sludge on its biodegradability and to assess the effectiveness of modification of the sludge in the aspect of increase in the value of VFAs, as well as in the value of COD and in the degree of disintegration of the modified sludge. Increase in the susceptibility of excess sludge on biochemical decomposition under anaerobic conditions occurs through the destruction of cell walls in microorganisms and the release of the organic substances they contain before they are used by the bacteria which exist under anaerobic conditions during the process of anaerobic stabilization.

The obtained results allow for drawing the following conclusions:

1. In the case of thermal disintegration of excess sludge, the most favourable temperature was 70°C with the heating time 4.5 h, for which the highest level of COD among all the temperatures and times of thermal treatment was obtained (2398 mg O_2/dm^3).
2. As a result of subjecting excess sludge (mixture A) to the process of anaerobic stabilization of raw excess sludge, the degree of fermentation of 16.88% was obtained

Table 4. Selected physical and chemical parameters of the mixture B (excess sludge, thermally disintegrated at the temperature of 50°C for 6 h + fermented sludge) subjected to the process of 8-day anaerobic stabilization

Time of methane fermentation	**Dry mass**	**Dry min. mass**	**Dry org. mass**	**VFAs**	**COD**	**Alkalinity**	**Acidity**	**Ammonium nitrogen**	**Nitrogen**	**pH**
d	g/dm^3	g/dm^3	g/dm^3	$mgCH_3COOH/dm^3$	mgO_2/dm^3	$mgCaCO_3/dm^3$	mg/dm^3	$mgN\text{-}NH_4^+/dm^3$	mgN/dm^3	–
0	9.30	2.93	6.37	188.57	640	450	4	22.4	112	7.00
1	7.78	2.09	5.69	788.57	1179	860	80	140	140	7.01
2	8.56	2.48	6.09	874.29	1344	956	100	142.8	182	7.03
3	8.29	2.85	5.44	840.00	1320	1060	110	226.8	173.6	7.09
4	6.55	2.62	4.43	617.14	1150	1120	70	170.8	190	7.71
5	5.95	2.18	4.74	522.86	892	1170	70	224	229.6	7.53
6	5.91	2.70	4.70	360.00	576	1240	72	249.2	277.2	7.16
7	5.40	3.84	4.46	188.57	621	1380	80	254.8	254.8	7.38
8	5.43	3.76	4.41	171.43	280	1440	66	252	196	7.76

Table 5. Selected physical and chemical parameters of the mixture C (excess sludge, thermally disintegrated at the temperature of 70°C for 4.5 h + fermented sludge) subjected to the process of 8-day anaerobic stabilization

Time of methane fermentation	**Dry mass**	**Dry min. mass**	**Dry org. mass**	**VFAs**	**COD**	**Alkalinity**	**Acidity**	**Ammonium nitrogen**	**Nitrogen**	**pH**
d	g/dm^3	g/dm^3	g/dm^3	$mgCH_3COOH/dm^3$	mgO_2/dm^3	$mgCaCO_3/dm^3$	mg/dm^3	$mgN\text{-}NH_4^+/dm^3$	mgN/dm^3	–
0	10.93	3.69	7.24	342.86	1826	550	40	168	196	7.67
1	11.01	3.33	7.68	891.43	1680	840	60	196	112	7.37
2	10.79	3.60	7.19	1131.43	1778	900	154	238	252	7.21
3	9.40	3.80	5.60	1062.86	1616	1000	180	260.4	308	7.08
4	9.91	4.00	5.91	891.43	1325	1020	200	282.8	252	7.23
5	9.98	4.39	5.59	737.14	997	1160	200	280	280	7.38
6	8.81	3.58	5.22	411.43	578	1300	180	280	280	7.49
7	8.68	3.33	5.35	685.71	882	1380	220	308	280	7.31
8	8.55	3.18	5.37	377.14	800	1420	240	322	336	7.32

after 8 days of fermentation. The maximal values of volatile fatty acids and COD (771.43 mg CH_3COOH/dm^3 and 1123 mg O_2/dm^3, respectively) were observed in the mixture on the 3rd day of the process.

3. In the case of the process of anaerobic stabilization of thermally disintegrated excess sludge, using the temperature of 50°C and heating time of 6h (Mixture B), and 70°C and heating time 4.5 h (mixture C), the following degrees of fermentation were obtained: 30.67% and 33.63%, respectively. Maximal levels of volatile fatty acids in mixtures B and C (874.29 and 1131.43 mg CH_3COOH/dm^3, respectively) were found on the 2nd day of the process. The obtained maximal level of VFA correlated with the maximal value of COD index found on the same (second) day of the process, which was 1344 mg O_2/dm^3 for mixture B and 1778 mg O_2/dm^3 for mixture C.

ACKNOWLEDGMENTS

Scientific work founded by grant BG 401/402/10 resource sponsored by the State Committee for Scientific Research (KBN) in the year 2010−2012.

REFERENCES

[1] Bień J., E. Neczaj, M. Worwąg, K. Wystalska: *Efektywność fermentacji metanowej osadów, Wodociągi-Kanalizacja*, **2 (84)**, 22−24 (2011).

[2] Bień J., M. Worwąg, K. Wystalska: *Możliwości zwiększenia efektywności przeróbki i ostatecznego zagospodarowania osadów ściekowych*, Forum Eksploatatora, **6 (45)**, 70−73 (2009).

[3] Bień J., E. Neczaj, M. Worwąg, M. Kowalczyk: *Intensyfikacja produkcji biogazu w procesie stabilizacji beztlenowej osadów przemysłowych*, Gospodarka odpadami komunlanymi, Monografia pod red. K. Szymańskiego, **6**, 211−218 (2010).

[4] Bień J., L. Wolny, P. Wolski: *Wpływ ultradźwięków na strukturę osadów ściekowych w procesie ich kondycjonowania*, XII Konferencja Naukowo-Techniczna pod red. J. Bienia, Osady ściekowe – problem aktualny, Częstochowa, 40−50 (2001).

[5] Zhang G., P. Zhang, J. Yang, H. Liu: *Energy-efficient sludge sonification: Power and sludge characteristics*, Bioresource Technology, **99**, 9029−9031 (2008).

[6] Bień J.B.: *Osady ściekowe − teoria i praktyka*, Wydawnictwo Politechniki Częstochowskiej, Częstochowa 2002.

[7] Podedworna J., K. Umiejewska: *Technologia osadów ściekowych*, Oficyna wydawnicza Politechniki Warszawskiej, Warszawa 2008.

[8] Malej J.: *Generowanie lotnych kwasów tłuszczowych ze strumienia ścieków surowych oraz niektóre problemy ścieków dowożonych taborem asenizacyjnym*, Rocznik Ochrony Środowiska, **3**, 103−128 (2001).

[9] Karaczun Z. M., L. G. Indeka: *Ochrona środowiska*, Wydanie 2, Agencja Wydawnicza ARIES, Warszawa 1999.

[10] Myszograj S.: *Fermentacja metanowa osadów ściekowych hydrolizowanych termochemicznie*, Wydawnictwo Politechniki Częstochowskiej, **10 (2)**, 141–152, Częstochowa (2007).

[11] Skiadas I., H. Gavala, J. Lu, B. Ahring: *Thermal pretreatment of primary and secondary sludge at 70°C prior to anaerobic digestion*, 10-th World Congress on Anaerobic Digestion, Nat. Res., 1121–1124, Canada, Montreal (2004).

[12] Neyens E., J. Baeyens: *A review of thermal sludge pre-treatment processes to improve dewater ability*, Journal of Hazardous Materials, **B98**, 51−67 (2003).

[13] Wójtowicz A.: *Dezintegracja – wprowadzenie do zagadnienia*, Forum Eksploatatora **1 (22)**, 34–38 (2006).

[14] Dąbrowska L., A. Rosińska, M. Janosz-Rajczyk: *Heavy Metals and PCBs in sewage sludge during thermophilic digestion process*, Archives of Environmental Protection, **37 (3)**, 3−13 (2011).

[15] Polskie Normy (PN-9/C-04540/05), Wydawnictwo Normalizacyjne, Warszawa.

[16] Polskie Normy (PN-EN-12879), Wydawnictwo Normalizacyjne, Warszawa.

[17] Polskie Normy (PN-75/C-04616/04), Wydawnictwo Normalizacyjne, Warszawa.

[18] Polskie Normy (PN-91/C-04540/05), Wydawnictwo Normalizacyjne, Warszawa.
[19] International Measurements Standards ISO 7027.
[20] Polskie Normy (PN-73/C-04576/10), Wydawnictwo Normalizacyjne, Warszawa.
[21] Polskie Normy (PN-73/C-04576/02), Wydawnictwo Normalizacyjne, Warszawa.

WPŁYW TERMICZNEJ DEZINTEGRACJI OSADÓW NADMIERNYCH NA EFEKTYWNOŚĆ PROCESU HYDROLIZY W STABILIZACJI BEZTLENOWEJ

Za czynnik wpływający w istotny sposób na szybkość biodegradacji osadów uważany jest stopień upłynnienia nierozpuszczalnych polimerów organicznych do postaci rozpuszczonej, warukującej dostępność substancji odżywczych dla mikroorganizmów. Fazami ograniczającymi szybkość beztlenowego rozkładu są faza hydrolityczna i metanogenna.

Poddanie osadów nadmiernych procesowi wstępnej dezintegracji znacząco wpływa na efektywność procesu stabilizacji beztlenowej. W wyniku intensyfikacji procesu hydrolizy, przejawiającej się wzrostem wartości oraz zwiększeniem szybkości generowania lotnych kwasów tłuszczowych (LKT), można zaobserwować wydłużenie fazy metanogennej procesu oraz wzrost stopnia przefermentowania modyfikowanych osadów. Zastosowanie wstępnej obróbki osadów ściekowych, tj. m.in. termicznej dezintegracji osadów, ma na celu rozbicie komórek mikroorganizmów oraz uwolnienie wewnatrzkomórkowej materii organicznej do fazy ciekłej. W wyniku zachodzącej hydrolizy termicznej osadów następuje już na etapie procesu kondycjonowania generowanie lotnych kwasów tłuszczowych (LKT). Uzyskana wartość LKT determinuje przebieg hydrolizy biologicznej, stanowiącej pierwszą fazę stabilizacji beztlenowej. Celem badań było określenie wpływu termicznej dezintegracji osadów nadmiernych na efektywność procesu hydrolizy w stabilizacji beztlenowej, tj. szybkość produkcji lotnych kwasów tłuszczowych, zmiany wartości ChZT oraz wzrost stopnia redukcji substancji organicznych. W pierwszym etapie badań dokonano określenia najkorzystniejszych warunków termicznej dezintegracji osadów nadmiernych stosując temperaturę 50°C, 70°C, 90°C i czas ogrzewania 1,5 h − 6 h. Osady umieszczone w kolbach laboratoryjnych, zamknięte szklanym korkiem z rurką manometryczną, poddano termicznej obróbce w łaźni wodnej z wytrząsaniem. W kolejnym etapie przeprowadzono 8-dobowy proces stabilizacji beztlenowej surowych oraz dezintegrowanych termicznie osadów nadmiernych. Stabilizacje prowadzono w mezofilowym reżimie temperatur tj. 37°C, w warunkach okresowych. W przypadku procesu stabilizacji beztlenowej termicznie dezintegrowanych osadów nadmiernych w temperaturze 50°C i czasie ogrzewania 6 h (Mieszanina B) oraz 70°C i czasie ogrzewania 4,5 h (Mieszanina C) uzyskano stopień przefermentowania wynoszący odpowiednio: 30,67% oraz 33,63%. Dla badanych osadów, tj. Mieszaniny B oraz C, maksymalną wartość lotnych kwasów tłuszczowych, tj. 874,29 mg CH_3COOH/dm^3 i 1131,43 mg CH_3COOH/dm^3, uzyskano w 2 dobie procesu. Z otrzymaną maksymalną wartością LKT korelowała odnotowana w ww. dobie procesu maksymalna wartość wskaźnika ChZT, wynosząca dla mieszaniny B 1344 mg O_2/dm^3, natomiast dla Mieszaniny C 1778 mg O_2/dm^3.