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Dewatering of initially conditioned excess sludge after fermentation

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ABSTRACT

Increasingly more sewage sludge which is generated today causes the efficient management based on the economic criteria to become a key issue. Sludge treatment that uses the stabilization process and dewatering are the most important and the most expensive processes. Construction of dewatering devices and stabilization of sewage sludge accounts for almost 50% of the total cost of construction in sewage treatment plants. Stabilized sewage sludge does not decay, has no bad smell, it is safe in sanitary terms and more suitable for dewatering. Previous studies have demonstrated that conditioning of excess sludge with ultrasound field after methane fermentation positively affects the levels of COD and VFA in supernatant liquor. Stabilization initially aided with conditioning improves the process of sludge fermentation and consequently affects the final susceptibility of the sludge to dewatering. The paper presents the investigations carried out for the sludge from communal sludge treatment and the sludge from cellulose industry. The studied sludge was initially conditioned with the ultrasonic field and then stabilized in order to determine the final parameters of their dewatering. Sonication of the sludge contributed to improvement in the degree of thickening. Conditioning caused an increase in the capillary suction time and specific resistance of the sludge. Some improvement regarding those parameters was found in the sludge after the fermentation process.

Keywords: Sewage sludge; Dewatering; Conditioning; Ultrasound field; Fermentation

1. Introduction

An intensive increase in the amount of sludge in sewage treatment plants that results from increasingly higher amount of sludge has made it necessary to develop some new methods and solutions for their final treatment [1–3]. In order to reduce this problem and its negative impact on the environment, scientists are conducting extensive studies that demonstrate a positive effect of the repeated use of sludge with simultaneous improvement in the processes that lead to reduction in its mass, volume and costs [4–7]. A

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key role is played by the methods of conditioning which are aimed at changes in the properties of the sludge. This causes faster and more efficient removal of water contained in the sludge [8,9]. Apart from conventional methods of conditioning through application of polyelectrolytes, new unconventional solutions (e.g. those that utilize ultrasound field) are also being developed [10,11].

One of the main processes concerning treatment of sewage sludge is stabilization. The method prevents generation of easily soluble compounds and prevents the sludge against decaying or having a bad smell, which negatively affects the environment [12]. An initial modification of the sludge before the fermentation process (conditioning) causes some changes in physicochemical composition affecting directly the intensification of the stabilization process being discussed [13–15].

2. Methodology

The study examined excess sewage sludge from the cellulose industry as well as from treatment of industrial and domestic waste. The role of an inoculum was played by the fermented sludge which accounted for 10% of the overall amount of the sludge used in the study. The cellulose sludge sampled for the study was characterized by the following contents: dry matter—16.80 g/dm^3, initial hydration—98.32%, capillary suction time (CST)—27 s and specific resistance of the sludge—7.08×10^{11} m/kg. The excess sludge from the treatment of wastewater had the following contents: dry matter—8.30 g/dm^3, initial hydration—99.17%, CST—227 s and specific resistance of the sludge—4.88×10^{12} m/kg.

Before the stabilization process, initial conditioning of sewage sludge was based on using energy of the ultrasound field by means of an ultrasonic processor with power of 1,500 W and frequency of 20 kHz. Two ultrasonic field wavelengths, 31.54 μm (which corresponded to 80% of maximum wavelength) and 39.42 μm (which corresponded to 100% of maximum ultrasonic field wavelength) were used in the study. The process of exposure to the ultrasonic field for each of the tests was carried out for the volume of 500 cm^3 for 5 min. Parameters of sonication were selected based on initial studies.

Non-conditioned sludge and the sludge initially conditioned with the ultrasound field were subjected to fermentation process in 10 laboratory flasks ($V = 0.5$ dm^3) and a bioreactor (7 dm^3). The stabilization process was continued for 10 d in the flasks and for 25 d in the bioreactor. In order to ensure the optimum temperature for mesophilic fermentation (±35°C), the flasks were kept in a laboratory thermostat. One flask was removed each day in order to determine dry matter content, CST and degree of thickening.

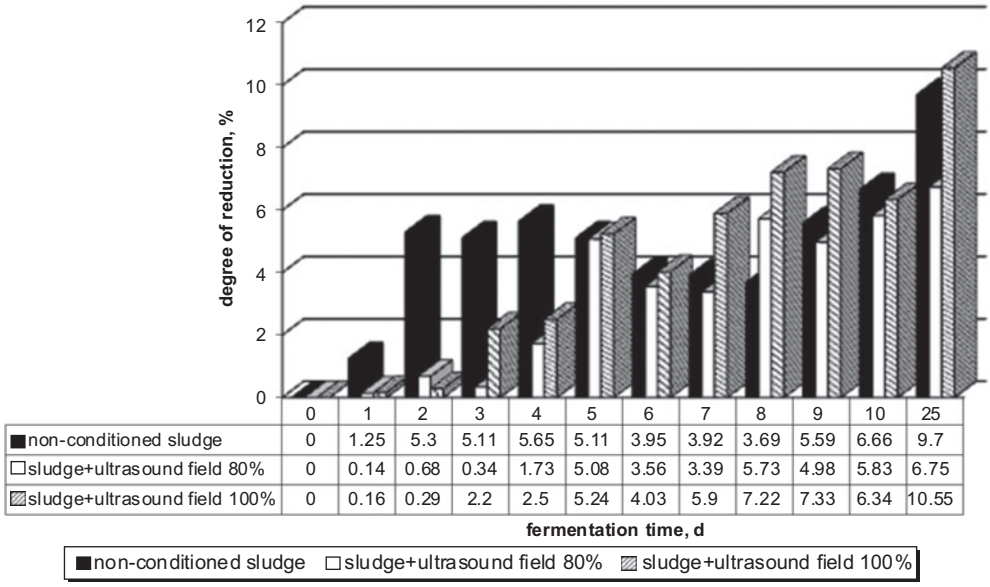
3. Results

Initial conditioning of excess sludge with the energy of ultrasonic field affects the degree of disintegration of sludge particles and leads to destruction of the cells of micro-organisms, which represents a precondition for acceleration of the process of hydrolysis while limiting the stabilization process. Shortening of the hydrolytic phase of anaerobic stabilization involves an increase in the degree of sludge fermentation and consequently the degree of dry matter fermentation.

Sewage sludge from paper production after fermentation exhibited the degree of dry matter reduction which was being improved on each day (Fig. 1). With respect to the content of non-fermented sludge (0 d), the degree of dry matter reduction in flasks on the 10th day was ca. 7%, whereas in the case of bioreactor, this value on the 25th day reached 9.7%. Initially conditioned sewage sludge with the energy of the ultrasound field caused an insignificant increase in the degree of dry matter reduction. In the sludge after fermentation, supported with exposure to the ultrasound field with wavelength of 39.42 μm, a 10.5% reduction in dry matter was observed after 25 d of the process, which was higher by ca. 1% with respect to the sludge which was not conditioned initially. It was found that an increase in the degree of dry mass reduction occurred on the 4th day of the process i.e. after the process of hydrolysis.

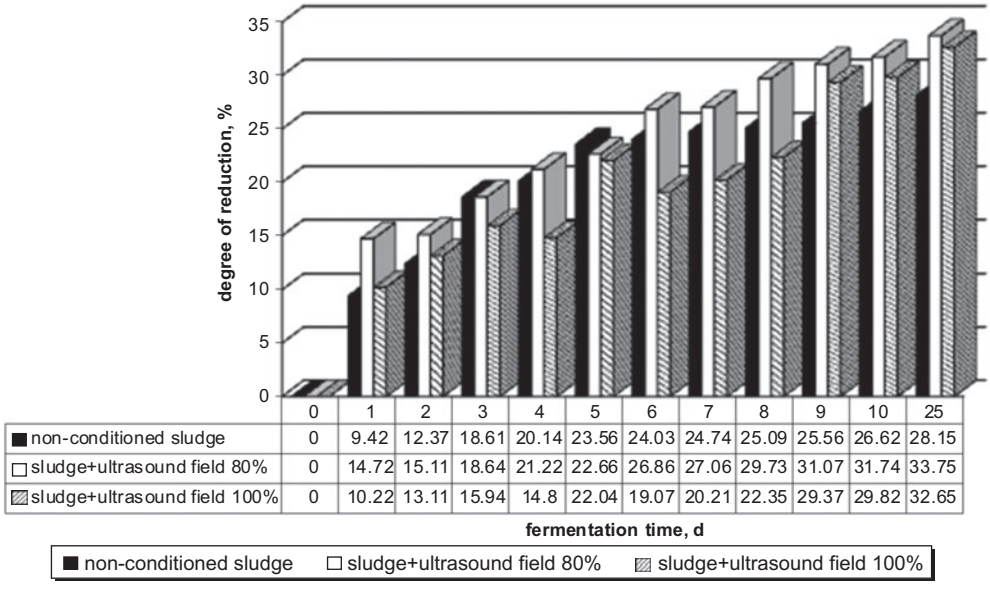
An increase in the degree of dry mass reduction on each day of the stabilization process was also found for the sewage sludge from the treatment of municipal wastewater (Fig. 2). Much higher values of dry matter reduction were reported for municipal waste compared to the waste from the paper industry. After 25 d of the fermentation process, the degree of reduction for the non-conditioned sludge was 28%. The energy of ultrasonic field affected some further increase in the parameter studied and reached the value of 33% for the two amplitudes studied.

Initial conditioning and fermentation of sewage sludge affected the parameters that characterize dewatering efficiency to different degrees. The sludge from paper wastewater treatment showed low values of CST at the level of 27 s (Fig. 3). Fermentation of this



	0	1	2	3	4	5	6	7	8	9	10	25
non-conditioned sludge	0	1.25	5.3	5.11	5.65	5.11	3.95	3.92	3.69	5.59	6.66	9.7
sludge+ultrasound field 80%	0	0.14	0.68	0.34	1.73	5.08	3.56	3.39	5.73	4.98	5.83	6.75
sludge+ultrasound field 100%	0	0.16	0.29	2.2	2.5	5.24	4.03	5.9	7.22	7.33	6.34	10.55

Fig. 1. Degree of dry matter reduction in the sludge from municipal wastewater treatment subjected to fermentation.

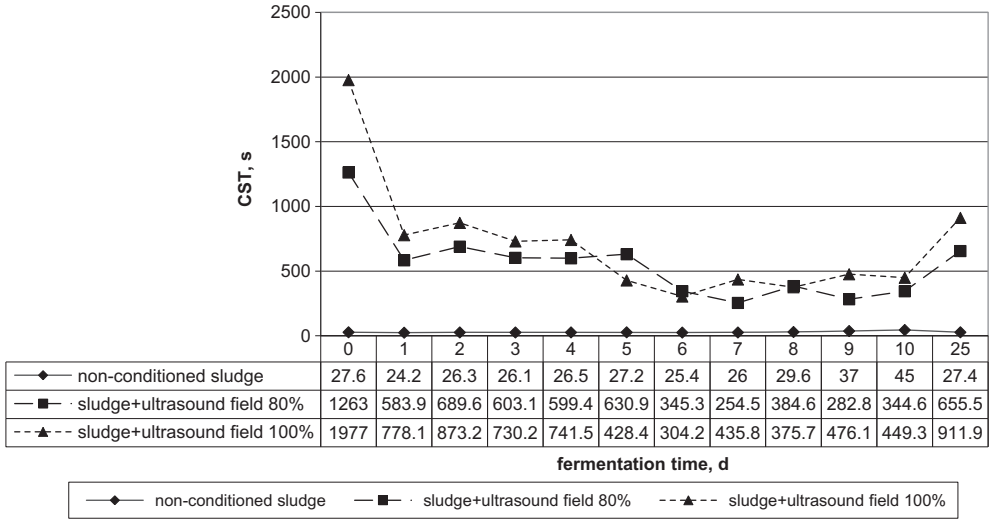


	0	1	2	3	4	5	6	7	8	9	10	25
non-conditioned sludge	0	9.42	12.37	18.61	20.14	23.56	24.03	24.74	25.09	25.56	26.62	28.15
sludge+ultrasound field 80%	0	14.72	15.11	18.64	21.22	22.66	26.86	27.06	29.73	31.07	31.74	33.75
sludge+ultrasound field 100%	0	10.22	13.11	15.94	14.8	22.04	19.07	20.21	22.35	29.37	29.82	32.65

Fig. 2. Degree of dry matter reduction from municipal wastewater treatment subjected to fermentation.

sludge caused no change in the parameter studied. Utilization of the energy of ultrasounds for conditioning of this sludge caused an increase in CST. Considering the sludge conditioned with the amplitude of 80%, CST amounted to 1,263 s, whereas for the amplitude of 100% this value was 1,977 s. Deterioration of the parameter discussed was caused by the dispersion of sludge flocs and, consequently, clogging of pores in the filtration paper, which had a direct effect on the elongation of CST.

Fermentation process caused an improvement in the filtration capability of sewage sludge after conditioning with the ultrasonic field. On the first day of the process, CST reduced by 50% and reached 583 s (amplitude of 80%) and 778 s (amplitude of 100%). Further tendency of the decrease in the parameter discussed was observed on each day and it reached 344 and 449 s on the 10th day. CST for the sewage sludge after processing in the bioreactor was higher



	0	1	2	3	4	5	6	7	8	9	10	25
non-conditioned sludge	27.6	24.2	26.3	26.1	26.5	27.2	25.4	26	29.6	37	45	27.4
sludge+ultrasound field 80%	1263	583.9	689.6	603.1	599.4	630.9	345.3	254.5	384.6	282.8	344.6	655.5
sludge+ultrasound field 100%	1977	778.1	873.2	730.2	741.5	428.4	304.2	435.8	375.7	476.1	449.3	911.9

Fig. 3. CST in the sludge from municipal wastewater treatment after fermentation.

with respect to the final day of the process carried out in flasks and reaches 655 s (80%) and 911 s (100%).

Deterioration of the filtration capability expressed with the values of CST did not correlate with the capability of the sludge for thickening (Fig. 4). Sewage sludge exposed to the ultrasonic field after the process of hydrolysis showed improved thickening efficiency and reached, on the 6th day, values lower with respect to the non-conditioned sludge. In the samples subjected to stabilization in the bioreactor after 25 d of the process, no improvement in thickening capability was found for the sludge initially conditioned with the energy of the ultrasonic field.

Similar pattern for CST with respect to the sludge from paper mills was observed in the sludge from treatment of municipal wastewater (Fig. 5). Non-fermented sludge which was not initially conditioned showed the CST value of 52 s. Fermentation of this sludge caused deterioration in filtration capability expressed by the degree of CST on the 10th day of the stabilization process to 86 s.

After the fermentation process in bioreactor, the value of the parameter discussed reached 227 s. Also in this case, conditioning with the ultrasonic field caused elongation of the CST to 1,874 s (amplitude of 80%) and 2,352 s (amplitude of 100%). The fermentation process improved the parameter discussed, which was noticeable as early as on the first days of stabilization. A tendency of decline in CST was maintained up to the 10th day of the process carried out in the flasks and

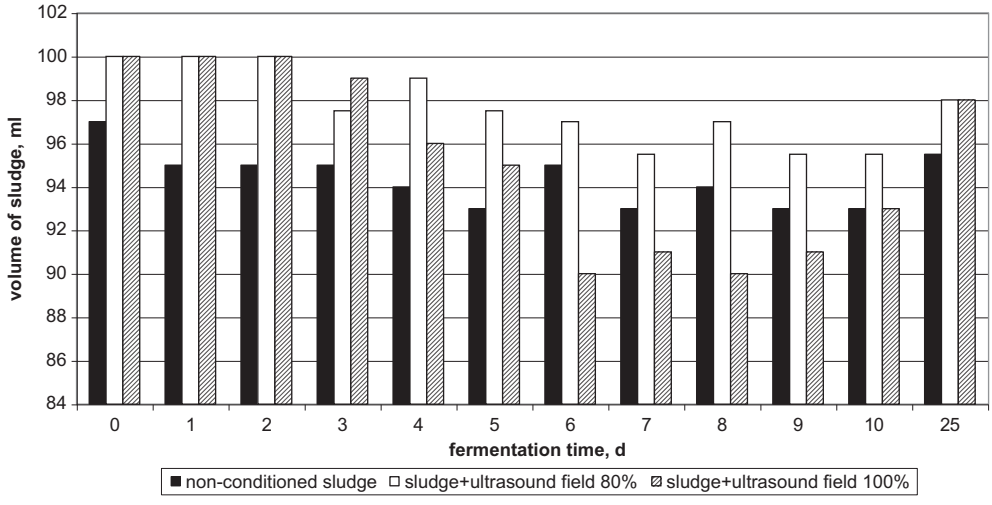
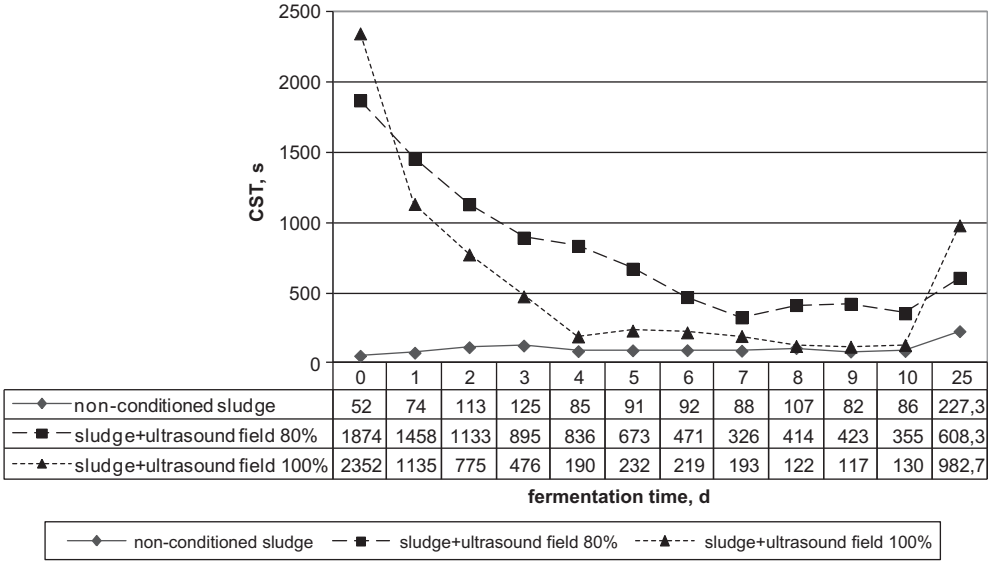


Fig. 4. Thickening of the sludge from municipal wastewater treatment after fermentation.



	0	1	2	3	4	5	6	7	8	9	10	25
non-conditioned sludge	52	74	113	125	85	91	92	88	107	82	86	227,3
sludge+ultrasound field 80%	1874	1458	1133	895	836	673	471	326	414	423	355	608,3
sludge+ultrasound field 100%	2352	1135	775	476	190	232	219	193	122	117	130	982,7

Fig. 5. CST in the sludge from municipal wastewater treatment after fermentation.

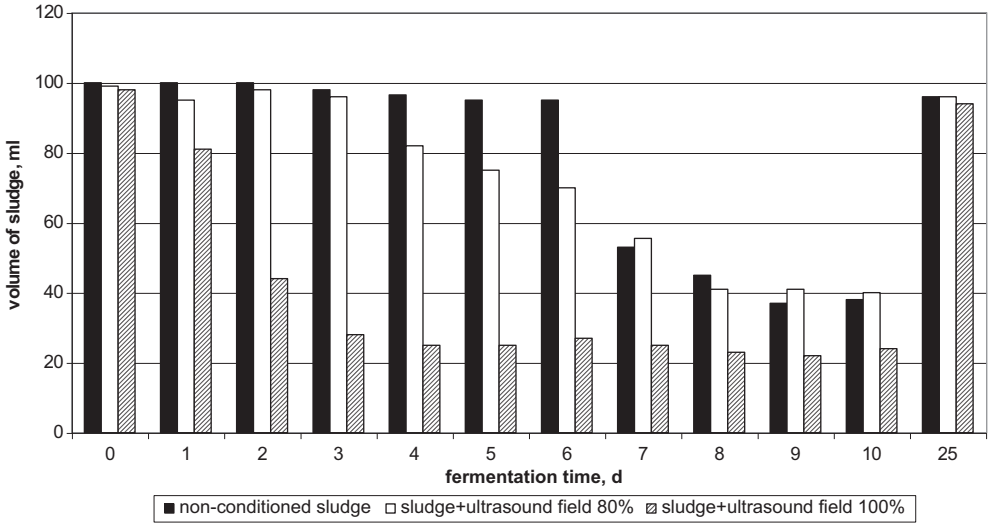


Fig. 6. Thickening of the sludge from municipal wastewater treatment after fermentation.

reached, for the sludge initially conditioned with the ultrasound field (amplitude of 100%), the value of 130 s.

The use of the ultrasonic field and fermentation had a substantial effect on improvement in the thickening capability in the sludge from treatment of industrial and domestic waste (Fig. 6). The initially conditioned (0 d) non-fermented sludge sedimented better compared to the initially non-conditioned sludge. Some further decline in the volume of sludge was being reported on each day of fermentation, reaching the lowest levels (25 ml) on the final day of hydrolysis (the 4th day). With sewage sludge after bioreactor, the final effect was lower. However, the effect of initial conditioning with ultrasonic energy was noticeable and reached lower final volumes for the sludge after initial conditioning.

4. Conclusions

Application of the energy of ultrasonic field for sewage sludge conditioning involves changes in their structure and, consequently, physicochemical parameters. Stabilization of the sludge initially conditioned with the ultrasonic field affects a decrease in the degree of dry matter reduction compared to the non-conditioned sludge. The dispersed sludge particles were

mineralized much better. Among the two types of the sewage sludge studied, the sludge from treatment of industrial and domestic waste was more susceptible to the effect of the conditioning agent and consequently to the final effect of the degree of dry matter reduction.

Fragmentation of sludge flocs caused elongation of CST in both the types of sludge studied. A substantial increase in CST was reported for the sludge from the cellulose industry for which, after 25 d of fermentation, the value rose to 911 s (sludge + ultrasonic field 100%) from 37 s (non-conditioned sludge). A dispersive effect of ultrasounds caused an increase in CST. However, stabilization caused a reduction in this parameter.

Despite deteriorated filtration capability that resulted from fragmentation and clogging of pores in the filtration partition wall, initial conditioning had a positive effect on improvement in the sedimentation capabilities. The sludge was better thickened when exposed to the effect of the ultrasonic field with the wavelength of 39.42 μm.

The results of the examinations led to the following final conclusions:

(1) Among the two types of the sewage sludge studied, the sludge from treatment of industrial and domestic sewage sludge was more susceptible to the effect of the ultrasonic field.
(2) Fermentation of the sewage sludge contributed to a higher degree of dry mass reduction. For the sludge conditioned with the ultrasonic field after stabilization, a higher degree of dry matter reduction was observed as compared to the non-conditioned sludge.
(3) The dispersive effect of the ultrasonic field contributed to an increase in the CST. Stabilization had a positive effect on the reduction and improvement in filtration capability in the parameter discussed.
(4) Application of the ultrasound field caused an improvement in sedimentation capabilities of the sludge subjected to the test.

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References

[1] J. Bień, Osady ściekowe – teoria i praktyka [Sewage sludge-theory and practice], Wydawnictwo Politechniki Częstochowskiej, Częstochowa, 2007.
[2] E. Stańczyk-Mazanek, M. Piątek, U. Kępa, Wpływ następczy osadów ściekowych stosowanych na glebach piaszczystych na właściwości kompleksu sorpcyjnego [Effect of sewage sludge applied to sandy soils on the sorption complex properties], Annu. Set Environ. Prot. 15(3) (2013) 2437–2451.
[3] E. Stańczyk-Mazanek, L. Stępniak, U. Kępa, Degradation of polycyclic aromatic hydrocarbons in soil with sewage sludges, Desalin. Water Treat. 10 (2009) 158–164.
[4] X. Feng, J. Deng, H. Lei, T. Bai, Q. Fan, Z. Li, Dewaterability of waste activated sludge with ultrasound conditioning, Bioresour. Technol. 100 (2009) 1074–1081.
[5] H.P. Yuan, X.-B. Cheng, S.P. Chen, N.W. Zhu, Z.Y. Zhou, New sludge pretreatment method to improve dewaterability of waste activated sludge, Bioresour. Technol. 102 (2011) 5659–5664.
[6] Z. Li, W. Li, Technological parameters of exceed sludge anaerobic digestion in industrial wastewater treatment plant, Electron. J. Geotech. Eng. 14 (2009) 1–11.
[7] D. Wielgórka, Innovative ecological activities in small and medium enterprises in Poland—Sources of financing, Annu. Set Environ. Prot. 15(1) (2013) 606–620.
[8] M. Małkowski, P. Wolski, Impact of thermal conditioning on the effectiveness of sewage sludge dewatering after anaerobic stabilization, Eng. Prot. Environ. 13(2) (2010) 103–109.
[9] H. Li, Y. Jin, B.M. Rasool, Z. Wang, Y. Nie, Effects of ultrasonic disintegration on sludge microbial activity and dewaterability, J. Hazard. Mater. 161 (2009) 1421–1426.
[10] I. Zawieja, L. Wolny, Effect of sonicator power on the biodegradability of sewage sludge, Annu. Set Environ. Prot. 13(2) (2011) 1719–1730.
[11] S. Na, Y. Kim, J. Khim, Physiochemical properties of digested sewage sludge with ultrasonic treatment, Ultrason. Sonochem. 14 (2007) 281–285.
[12] I. Zawieja, P. Wolski, Effect of chemical—Thermal modification of excess sludge on the volatile fatty acids generation during acid fermentation process, Annu. Set Environ. Prot. 15 (2013) 2054–2070.
[13] I. Zawieja, L. Wolny, P. Wolski, Influence of excessive sludge conditioning on the efficiency of anaerobic stabilization process and biogas generation, Desalination 222 (2008) 34–7381.
[14] P. Wolski, L. Wolny, Effect of disintegration and fermentation on the susceptibility of sewage sludge to dewatering, Annual Set Environ. Prot. 13 (2011) 1697–1706.
[15] T.I. Onyeche, O. Schläfer, H. Bormann, C. Schröder, M. Sievers, Ultrasonic cell disruption of stabilised sludge with subsequent anaerobic digestion, Ultrasonics 40 (2002) 31–35.